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INFLUENCE OF SOCIALLY USED DRUGS ON VISION AND VISION
PERFORMANCE

OPTICAL SCIENCES GROUP

PREPARED FOR
ARMY MEDICAL RESEARCH AND DEVELOPMENT COMMAND

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C) Optokinetic nystagmus (OKN) induced by vertical black bars moving horizontally across a 100 degree-wide field, was assessed qualitatively to have decreased saccadic frequency and amplitude, and to become less regular, after alcohol intoxication.

D) Sinusoidal pursuit eye movements were limited in their high frequency response after alcohol; marijuana, however, did not reduce this maximum velocity function.

E) Sinusoidal pursuit eye movements deteriorated markedly after alcohol and slightly after marijuana for intermittently-seen targets.

F) Glare recovery time (GRT) was reduced (i.e., improved) for high contrast stripes, and increased for low contrast stripes by alcohol and marijuana.

G) Visual acuity measured psychometrically with Landolt rings and with variable contrast spots did not change after marijuana intoxication.

H) Spot luminance thresholds 25 degrees in the retinal periphery were unaffected by alcohol and were slightly increased by marijuana.

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ON VISION AND VISION PERFORMANCE

ANNUAL REPORT

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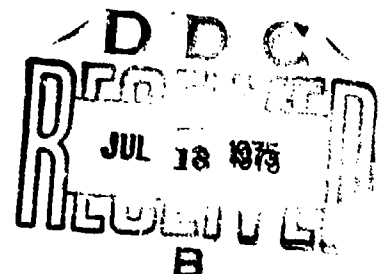
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FOREWORD

This Annual Report was written for the U.S. Army Medical Research and Development Command by the investigators of a three-year study which was supported by a U.S. Army Basic Contract (No. DADA17-73-C-3106) awarded to the Visual Sciences Division of the Optical Sciences Group, San Rafael, California, which directed, guided and administered the research study. The experimental phases of the study were conducted at the Smith-Kettlewell Institute of Visual Sciences in the Pacific Medical Center in San Francisco. We gratefully acknowledge the space, facilities, and services provided by the Institute.

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Through the efforts of the above-mentioned agencies, institutions, and people, the results of this study were made possible. The Optical Sciences Group and we accept responsibility for the contents of this report.

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TABLE OF CONTENTS

	Page
Foreword	2
Abstract	6
I. Introduction	7
II. General Experimental Methods	8
III. Special Vision Testing Facility	11
IV. Specific Experiments	13
A. Intraocular Pressure	13
B. Heterophoria	18
C. Optokinetic Nystagmus	21
D. Sinusoidal Pursuit Eye Movements:	
Maximum Velocity	22
E. Sinusoidal Pursuit Eye Movements:	
Reduced Information	24
F. Glare Recovery	28
G. Visual Acuity	32
H. Spot Luminance Thresholds	34
V. Summary and Conclusions	37
VI. Literature Cited	38

	Page
VII. Figures	
Fig. 1. Subjects' Waiting Room	9
Fig. 2. Special Vision Testing Facility ("White Room")	10
Fig. 3. White Room: Optical System	11
Fig. 4. Dose Effects of Marijuana on Intraocular Pressure	17
Fig. 5. Change In Heterophoria: Alcohol	20
Fig. 6. Sinusoidal Pursuit Eye Movements: Alcohol and Placebo	23
Fig. 7. Sinusoidal Pursuit Eye Movements: Marijuana and Placebo	24
Fig. 8. Sinusoidal Eye Movements with Reduced Information Stimuli: Alcohol and Placebo	26
Fig. 9. Sinusoidal Eye Movements with Reduced Information Stimuli: Marijuana and Placebo	27
Fig. 10. Glare Recovery: Alcohol (Low and High Contrast Stripes)	29
Fig. 11. Glare Recovery: Marijuana (12, 22 mg THC and Placebo for S-127)	31
Fig. 12. Glare Recovery: Marijuana (12, 22 mg THC and Placebo for S-128)	32
Fig. 13. Visual Acuity: Marijuana (12, 22 mg THC and Placebo for S-127)	33
Fig. 14. Visual Acuity: Marijuana (12, 22 mg THC and Placebo for S-128)	34
Fig. 15. Spot Luminance Increment Thresholds (Alcohol and Marijuana)	36

	Page
VIII. Tables	
Table I. Intraocular Pressure: Alcohol and Placebo	14
Table II. Relaxation Scale: Alcohol and Placebo	14
Table III. Time Course of Intraocular Pressure, Pulse Rate, High Rating and Relaxation: Alcohol and Placebo	15
Table IV. Intraocular Pressure: Marijuana (22 mg THC) and Placebo	15
Table V. Intraocular Pressure: Marijuana (12 mg THC) and Placebo	16
Table VI. Intraocular Pressure: Marijuana (8 and 15 mg THC) and Placebo	16
Table VII. Relaxation Scale: Marijuana (8 and 15 mg THC) and Placebo	18
Table VIII. Heterophoria (Von Graefe): Alcohol and Placebo	19
Table IX. Heterophoria (Automated Phoria Device): Alcohol and Placebo	20
Table X. Heterophoria (Von Graefe and Automated Phoria Device): Marijuana and Placebo	21
Table XI. Maximum Velocity of Sinusoidal Smooth Pursuit Movements: Alcohol and Placebo.	22
Table XII. Maximum Velocity of Sinusoidal Smooth Pursuit Movements: Marijuana and Placebo	23
Table XIII. Eye Movement Parameters for Sinusoidal Tracking of Reduced Information Stimulus: Marijuana and Placebo	25
Table XIV. Eye Movement Parameters for Sinusoidal Tracking of Reduced Information Stimulus: Marijuana and Placebo	27
Table XV. Glare Recovery Time (High Contrast Stripes): Alcohol and Placebo	28
Table XVI. Glare Recovery Time (Low Contrast Stripes): Alcohol and Placebo	30
Table XVII. Glare Recovery Time (Low Contrast Stripes): Marijuana (12, 22 mg) and Placebo	31
Table XVIII. Visual Acuity: Marijuana (12 and 22 mg THC) and Placebo	33
Table XIX. Spot Luminance Increment Thresholds: Alcohol (0.5, 1.0 ml/kg), Marijuana (8, 15 mg THC), and Placebo	35

ABSTRACT

Seven vision functions were measured in a study sample of 19 experienced, male marijuana users under the influence of alcohol or marijuana. Experiments were performed with placebo controls in a double-blind fashion with a cross-over design.

The experimentally obtained results are:

A) Intraocular pressure (IOP) was reduced slightly by alcohol and more by marijuana for "equivalent" levels of intoxication. For 5 concentrations of tetrahydrocannabinol (THC) up to 22 mg THC, a typical dose relationship curve was established for IOP drop and marijuana (THC) dose. For both alcohol and marijuana, IOP drop seems to be related to the extent of drug-induced relaxation.

B) Phoria consistently shifts in a convergent (eso-ward) direction after either alcohol or marijuana. Comparison of measurements at distance (free-space) and at optical infinity (targets at 40 cm) indicate a change in instrument-induced (proximal) vergence after alcohol and possibly after marijuana.

C) Optokinetic nystagmus (OKN) induced by vertical black bars moving horizontally across a 100 degree-wide field, was assessed qualitatively to have decreased saccadic frequency and amplitude, and to become less regular, after alcohol intoxication.

D) Sinusoidal pursuit eye movements were limited in their high frequency response after alcohol; marijuana, however, did not reduce this maximum velocity function.

E) Sinusoidal pursuit eye movements deteriorated markedly after alcohol and slightly after marijuana for intermittently-seen targets.

F) Glare recovery time (GRT) was affected in the same general way by alcohol and marijuana: GRT was reduced (i.e., improved) for high contrast stripes, and increased for low contrast stripes.

G) Visual acuity measured psychometrically with 4-position Landolt rings and with variable contrast spots did not change after marijuana intoxication.

H) Spot luminance thresholds 25 degrees in the retinal periphery were unaffected by alcohol and were slightly increased by marijuana.

I. INTRODUCTION

In February, 1972, a U.S. Army Basic Contract (No. DADA17-72-C-2083) was awarded to the Optical Sciences Group, the long-range goal being the development of procedures for drug screening by automated vision testing. To realize this goal it was first necessary to establish which vision functions were altered by socially-used drugs. Objective and automated tests were selected to bypass the purely subjective drug effects and tap the vision functions directly. Marijuana was chosen as the drug of inquiry with alcohol serving as the reference drug.

The Report ("Objective Testing of Marijuana-Induced Vision Changes") for that contract described nine vision functions and six related functions that were investigated in the study (Jampolsky *et al.*, 1973).

Vision Functions

- 1) Glare recovery time
- 2) Phoria
- 3) Optokinetic nystagmus
- 4) Intraocular pressure
- 5) Saccadic eye movements
- 6) Sinusoidal pursuit eye movements
- 7) Pupil size
- 8) Conjunctival injection
- 9) Lid edema

Related Functions:

- 1) Reaction time
- 2) Time estimation
- 3) Time production
- 4) Pulse rate
- 5) Subjective evaluation of "high"
- 6) Subjective Drug Effects Questionnaire (SDEQ)

Nineteen, experienced, male, marijuana smokers comprised the study sample. The standard dose was a 0.8 gram natural marijuana cigarette containing 1.5 percent (12 milligrams) of delta-9-tetrahydrocannabinol (Δ^9 -THC). Placebo cigarettes were smoked as a control. The experiments were carried out double-blind with a cross-over design. That is, neither the subject nor the experimenter knew when the drug or placebo had been given; if marijuana (randomly chosen) was given on the first day, then placebo was given on the second day, and vice versa. Some of the subjects were also given alcohol, Librium, or a higher dose of marijuana (22 mg THC) in separate experiments.

Several important results were detailed in the Report.

1) Glare recovery time for high contrast stripes was decreased from a base-line level of about 3 sec by about 0.25 sec within 30 min after smoking the marijuana. This improvement in function persisted for 1 to 3 hr.

2) The pressure within the eye was reduced by smoking marijuana, but only for those subjects who experienced a substantial "high" and a state of peaceful relaxation from the experimental dose. An epiphenomenon, not specific to marijuana, accounts for most of the observed decrease in pressure.

3) Smooth following movements of the eyes to a small spot of light moving horizontally back and forth with increasing sinusoidal velocity were found to be impaired with alcohol but not with marijuana intoxication.

4) Pulse rate started to rise within 5 min after beginning to smoke marijuana and reached a maximum (about 38% above base-line) at about the time the subject completed smoking a cigarette (approximately 10 min). Maximum pulse increase was not significantly correlated with maximum "high" rating, relaxation from the experimental dose, or with previous marijuana experience.

5) From the 272 items in the Subjective Drug Effects Questionnaire (SDEQ), 6 items relating to peaceful relaxation and tiredness were found to discriminate between subjects who did and did not exhibit a decrease in IOP after smoking marijuana. The magnitude of the IOP drop was correlated significantly (+0.83) with the score on the relaxation scale.

5) Subjective high ratings, on a scale of zero to 100, were found to correlate significantly with degree of relaxation after smoking marijuana (0.62) and with IOP drop (0.57). In addition, the high ratings correlated (-0.61) with amount of previous marijuana experience, suggesting that greater use produces either a tolerance to certain marijuana effects or a change in scaling factor for "high" ratings.

Some additional and incomplete results were presented in the report,

1) Phoria as measured objectively and automatically in a box-type instrument at optical infinity showed no statistically significant change after the experimental doses of marijuana (N=14), alcohol (N=5), or Librium (N=3).

2) Optokinetic nystagmus was qualitatively assessed before and after smoking marijuana and was found in many, but not all, subjects to be reduced in amplitude, frequency, and regularity.

3) Reaction time was not affected by smoking marijuana.

4) About 30 min after smoking placebo, the saccadic eye movement rhythm (to a previously seen rhythmic target) slowed whereas it increased after smoking marijuana. This result is consistent with a speeding up of the internal clock with marijuana intoxication.

5) Time production decreased and time estimation increased after smoking marijuana, indicating a speeding up of the internal clock.

6) Pupil area decreased by about 10% 30 min after smoking marijuana.

7) Conjunctival injection was fairly consistently observed within 15 min after smoking marijuana.

8) Many, but not all, of the subjects exhibited a lid edema after smoking marijuana which resulted in an apparent ptosis (lid droop) caused by the fluid-heavy lids.

In May, 1973, a new U.S. Army Contract (No. DADA17-73-C-3106) was awarded to the Optical Sciences Group to determine the influence of socially-used drugs on vision and vision performance. The chief objective of this research was to use the experience and results obtained from the previous contract project to conduct a well-organized, broad-based, three-year investigative study of those sensory, motor, and physiological aspects of vision that may be influenced by socially-used drugs. Alcohol was chosen as the primary drug of inquiry with marijuana serving as the major reference drug, and with stimulants and depressants being additional reference drugs later in the study; polydrug effects would be investigated during the third year of the study.

This final report covers the influence of alcohol or marijuana on the following vision functions:

(Physiology)

A. Intraocular pressure

(Oculomotor)

B. Phoria

C. Optokinetic nystagmus

D. Sinusoidal eye movements

(Sensory-Perceptual)

E. Glare recovery

F. Visual acuity

G. Brightness discrimination

II. GENERAL EXPERIMENTAL METHODS

All of the experiments were conducted in the Smith-Kettlewell Institute of Visual Sciences (SKIVS) at the Pacific Medical Center in San Francisco, California. Associated with the laboratory at SKIVS was a special adjoining room with living-room type furnishings (e.g. soft chairs, end tables, radio, and pictures). On an experimental day the subjects spent all of their time in this room except when they were actually being tested in the adjoining laboratory. Drug administration (alcohol or marijuana) occurred in this room (see Fig. 1).

Nineteen male subjects participated in the experiments reported here; a number of subjects participated in more than one experiment. The subjects ranged in age from 19 to 27 years (average 21.4 years). The subjects had been screened by a psychiatrist to establish acceptability to the study; our marijuana subjects (who must have smoked marijuana at least five times and had no "bad trips" on marijuana) are in general "social drinkers" who drink beer, wine, or liquor at least once a week. All of the subjects used in the alcohol studies had at least this level of alcohol experience.



Fig. 1: Subjects' waiting area.

Subjects were told the general nature of the study and were given a brief description of each test to be performed. Each subject was asked to eat a light (low fat) breakfast on the day of an experiment and to arrange transportation so he would not have to drive home afterwards. The subjects stayed in the laboratory after the experiment until they were essentially "down." Those who were at all "high" or uncomfortable at the end of the day were sent home in a taxi. Payment for serving as a subject was \$2.00 per hour; a bonus schedule was used for return visits.

The experiments were generally carried out double-blind with a cross-over design. That is, neither the subject nor the experimenter on any day knew whether the drug or placebo had been given; if marijuana (randomly chosen) was given on the first day, then placebo was given on the second day, and vice versa. One of us (R.J.) was responsible for obtaining, maintaining, preparing, assaying, and dispensing the marijuana which was grown at the U.S. Government Research Center in Mississippi. The placebo was prepared locally by a method described by Jones and Stone (1970).

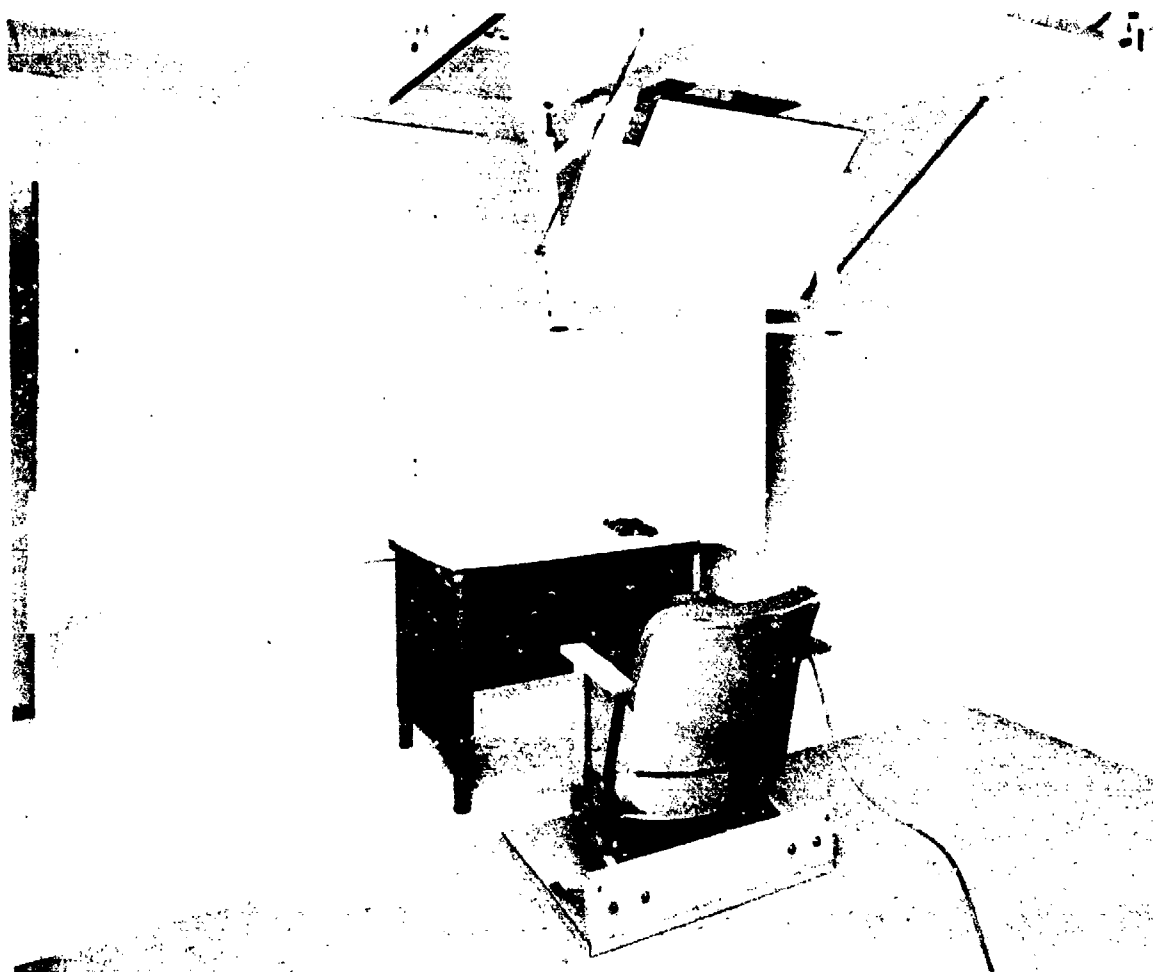


Fig. 2: Special vision testing facility ("White Room").

When the subjects reported to the laboratory, they were given one or more trials on the test(s) to establish a pre-drug baseline. Glasses were worn if necessary for good distance vision; contact lenses were not worn. During an experimental day, an attending physician (psychiatrist or ophthalmologist) was either in the laboratory or was immediately available. After taking the drug, measurements were performed immediately and were repeated at regular intervals throughout the day until recovery from the drug or return to measurement baseline occurred. A light lunch was provided for the subjects at mid-day at a convenient and appropriate time between experimental trials.

The standard alcohol treatments were 1.0 and 0.5 ml/kg of 95% ethanol. The alcohol was mixed with fruit juice to a total volume (ml) for each subject of 3 ml/kg body weight. This mixture, with 2 ice cubes added, was drunk in about 20 mins from a lidded cup through a straw. Two drops of peppermint or eucalyptus extract were placed on the lid of the cup together with 2 drops of alcohol so that the alcohol and placebo treatments looked, smelled, and tasted alike. These alcohol treatments produced blood alcohol levels of approximately 0.07% and 0.03% at 30 min after finishing the drink. Blood alcohol levels were measured by breath analysis using the Intoxilyzer (Omicron Systems Corporation, Palo Alto). Marijuana treatments were 0.8 gm cigarettes containing 8, 12, 15 or 22 mg of THC which were smoked for "maximum intake" in about 10 min.

In one experiment, subjects were required both to drink and smoke; the subjects were given only one experimental drug at each session (i.e., if a subject was given alcohol to drink, he was given a marijuana placebo to smoke and vice versa). This design is quite successful in maintaining the subject "blind" to the drug being administered. Many subjects were unable to tell whether they had drunk alcohol or smoked marijuana, especially at low doses; many were convinced that they had been given both.

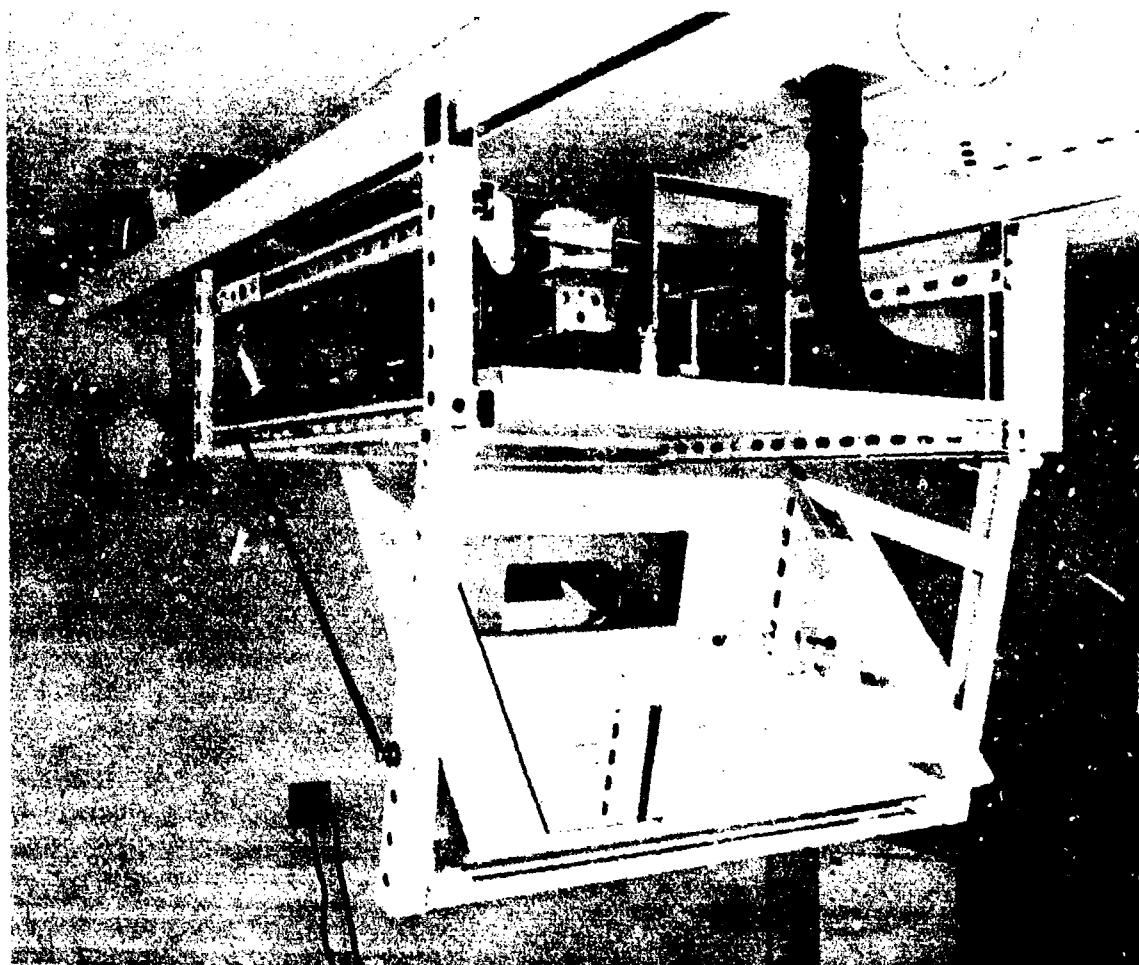


Fig. 3: Optical components of the White Room stimulus presentation system.

III. SPECIAL VISION TESTING FACILITY

A. Purpose

A multi-purpose, vision functions experimental test facility ("White Room") was conceived with the idea of providing great flexibility in presenting a wide variety of visual stimuli to measure a spectrum of vision functions. We considered it desirable to be able to set up new stimulus parameters quickly for new experiments, and to be capable of controlling targets for their size, position, movement, luminance, wavelength, and duration.

Targets should be able to be presented against backgrounds of variable luminance and of varying types. To automate stimulus presentation, we planned that many functions would be controlled from a Hewlett-Packard 9830A calculator. This calculator has a hard-wired BASIC compiler and cassette tape storage for programs and data; it provides a fairly slow calculating facility with flexibility and ease of programming for psychophysical experiments.

Fig. 2 shows a general view of the "White Room." There is a hemicylindrical projection screen 9 ft in radius at one end of the room. A multi-element, movable projection system (Fig. 3) is suspended from the ceiling above the centrally placed subject's chair. Extremely uniform illumination is provided on the screen; the walls, ceiling, and part of the floor are painted with photometric sphere paint which has very even diffusing properties. When the luminaries in the room are appropriately adjusted, the luminance variation across the projection screen is less than 2%.

B. Equipment and Functions

1. Power Supplies and Monitoring

Regulated AC power is provided to the projection and background lamps. Photo-transistors are used to monitor the light on the background screen and in the projection system. A digital voltmeter and rapid switching are provided so that these light levels, as well as associated voltages, may be checked at any time during the course of an experiment.

2. Target Presentation

Targets are projected onto the screen through a system of high quality lenses and front surface mirrors. The system is essentially removed from the field of view of the subject; it allows movement of the projected spot by control of one or more of the mirrors. The main projection system is a Kodak Random Access Ektagraphic projector, controlled from the H-P 9830A, so that any one of 80 slides may be selected in less than 2 sec. The projector provides precise slide positioning. An additional projection system projects small high luminance spots onto the screen.

3. Stimulus Luminance

The beam from the projector(s) passes through a high quality circular neutral density wedge (range 2 log units) which is mounted on a 200 step per revolution bidirectional stepping motor. The motor is controllable from the H-P 9830A, and thus luminance of the projected beam can be remotely and automatically controlled.

4. Stimulus Position and Movement

One component of the system of mirrors by which the projected beam reaches the screen is mounted on a galvanometer. This mirror is deflected horizontally by voltages applied to the galvanometer and thus produces horizontal movements of the spot on the screen. The galvanometer is controllable by voltages from the H-P 9830A or from an external waveform generator.

5. Shutter

The shutter is mounted so as to occlude the projected beam and is controllable through program statements. It consists of a vane mounted on a 90 degree stepper motor which can be programmed so that the vane takes up its position in any of the 4 quadrants. Rise time of the shutter is less than 5 msec and exposures as short as 50 msec can be specified.

6. Subject's Chair

The subject's chair (Fig. 2) has a response panel built into it which allows any of five different responses from the subject. These can be used to signal, for example, orientation of acuity targets, position of low contrast targets, or test endpoints. Inclusion of reaction time measurements within this system is a planned innovation.

7. Auditory Stimuli

Psychophysical experiments in vision often require that the subject be alerted to the presentation of upcoming stimuli or to periods in which stimuli may occur. The White Room has a tone generator, controlled by the H-P 9830A, which generates 16 different tone frequencies.

8. External Equipment

We are currently constructing a relay system to allow program control of external events. Ten independently switchable relays will be available to tie in, for example, auxiliary recording equipment, the projection system, white noise generators, or arrays of stimulus lights.

C. Future Development

Although the present system could be expanded to accept analogue data, the processing of such data for rapid interaction with relevant events (e.g., eye movements) is not possible with the H-P9830A. This limitation of needed White Room capability is now under study in terms of additional equipment needs.

IV. SPECIFIC EXPERIMENTS

A. Intraocular Pressure

1. Procedure

Measurements of IOP were made with an American Optical Non-Contact Tonometer. Topical anesthesia is not required. This instrument flattens the cornea with a calibrated puff of air, and determines the time taken to flatten the corneal apex. This time is a direct correlate of IOP.

At least 5 measurements of IOP were made at each trial; if the range of these measures exceeded 3 mm Hg, two further measurements were taken. Only right eyes were measured.

Two experiments were conducted. In the first, results were obtained from 8 subjects. Five different treatments were administered to the subjects double-blind in a balanced Latin-square design.

- a. Placebo alcohol and placebo marijuana
- b. 0.5 ml/kg alcohol and placebo marijuana
- c. 1.0 ml/kg alcohol and placebo marijuana
- d. Placebo alcohol and 8 mg THC
- e. Placebo alcohol and 15 mg THC

Immediately preceding each set of IOP measurements, the subjects filled in a 10-item questionnaire to determine their state of relaxation on a -8 to +32 scale. IOP measurements were made at 50 min and 20 min preceding the end of the smoke and drink period, as well as at 5, 80, and 150 min following this period.

In the second experiment, 6 subjects were given either placebo marijuana, 12 mg THC, or 22 mg THC in a double-blind cross-over design. At least two sets of IOP measurements were made before smoking, and further sets of measurements were made at 5, 30, 80, 120, 180, and 240 min after smoking.

2. Results and Comments

a. Alcohol

Table 1 shows the IOP measurements for the right eyes of 8 subjects given alcohol doses of 1.0 and 0.5 ml/kg, as well as alcohol placebo. The mean pressures tend to be lowest 80 min after drinking alcohol. With the 50 min pre-drink measurements taken as the baseline, the IOP drop was greater for the 1.0 ml/kg alcohol dose (-0.8 mm Hg) than for the 0.5 ml/kg dose (-0.3 mm Hg). The placebo produced essentially no IOP change at 5 and 80 post-drink, and a small increase in pressure 150 min after drinking. None of these IOP changes is statistically significant at the 5% level by the Walsh test (Siegel, 1956), but they are in general accord with the changes reported by Houle and Grant (1967) and in the previous report by Jampolsky *et al.* (1973).

The relaxation hypothesis as proposed by Flom *et al.* (1974) to account for some of the alcohol-induced drop in IOP is generally supported by the present results. For both doses, the post-80 min IOP change was negatively correlated with score on the 10-item relaxation scale (Spearman ranks correlation r_s -0.53 for high dose, -0.56 for low dose; $p > 0.05$), indicating a greater drop in IOP for subjects experiencing greater relaxation. The lack of statistical significance is probably attributable to the small sample size. Relaxation scores obtained during the course of the alcohol-IOP experiments are given in Table II. Mean values for other related variables are presented in Table III.

b. Marijuana

IOP dropped, although statistically insignificantly, with all 4 doses of marijuana (8, 12, 15, and 22 mg THC) as shown in Tables IV through VI. For 3 of the doses, the maximum IOP drop occurred at 80 min post-smoke, and for 1 (12 mg THC) the maximum drop occurred at 30 min post-smoke.

SUBJECT	ALCOHOL 1.0 ml/kg					ALCOHOL 0.5 ml/kg					ALCOHOL PLACEBO				
	Pre 50	Pre 20	Post 5	Post 80	Post 150	Pre 50	Pre 20	Post 5	Post 80	Post 150	Pre 50	Pre 20	Post 5	Post 80	Post 150
127	12.3	-	14.0	12.3	-	10.6	12.4	11.2	11.8	12.7	11.2	-	11.4	12.0	13.2
128	12.4	12.7	13.0	12.5	13.8	11.8	-	13.4	12.8	13.0	11.4	-	11.4	13.6	12.0
134	17.1	16.5	15.6	14.8	16.0	14.8	14.4	13.3	15.3	14.5	15.4	15.2	16.6	14.2	15.3
214	13.4	-	14.8	12.8	12.6	17.6	17.3	14.3	14.0	13.8	13.9	14.4	14.2	13.6	14.6
221	8.1	8.8	8.3	9.1	7.5	10.3	10.5	10.5	9.0	10.5	12.0	-	9.7	9.0	9.6
222	10.8	-	9.8	8.0	9.3	9.1	10.4	9.3	9.3	10.0	9.3	-	9.0	8.8	8.0
223	14.7	-	14.2	13.0	15.2	14.4	15.0	14.2	14.2	14.1	16.2	16.0	15.2	16.2	16.4
239	9.8	10.0	9.6	9.5	9.1	11.8	-	11.2	10.6	11.0	8.4	10.4	10.3	11.0	11.4
Mean	12.33	12.30	12.41	11.50	11.93	12.43	13.33	12.19	12.13	12.45	12.23	14.00	12.29	12.30	12.56
St. Dev.	2.93	3.42	2.77	2.35	3.31	2.96	2.73	1.87	2.35	1.73	2.77	2.49	2.73	2.59	2.88
Diff. Pre 50			0.08	-0.83	-0.40			-0.25	-0.30	0.02			0.06	0.07	0.33
% Diff.			0.6	-6.7	-3.2			-2.0	-2.4	0.1			0.5	0.6	2.7
Diff. Pre 20			0.01	-0.50	-0.07			-1.15	-1.20	-0.88			-1.71	-1.70	-1.44
% Diff.			3.4	-4.2	-0.6			-8.6	-9.0	-6.6			-12.2	-12.1	-10.3

Table I: Intraocular Pressure (mm HG): Alcohol (0.5 and 1.0 ml/kg) and Placebo. Eight Subjects.

SUBJECT	ALCOHOL 1.0 ml/kg					ALCOHOL 0.5 ml/kg					ALCOHOL PLACEBO				
	Pre 50	Pre 20	Post 5	Post 80	Post 150	Pre 50	Pre 20	Post 5	Post 80	Post 150	Pre 50	Pre 20	Post 5	Post 80	Post 150
127	6	-	19	16	-	6	7	6	6	6	6	-	10	6	6
128	4	4	11	13	8	4	-	4	4	5	4	-	4	4	4
134	3	3	9	5	4	3	3	4	3	3	3	3	4	3	3
214	3	-	5	8	10	2	5	3	7	9	4	4	-	4	3
221	8	7	5	7	14	4	6	6	4	10	3	-	7	4	-
222	5	-	23	20	13	5	5	16	7	5	0	-	7	6	8
223	-	11	7	11	8	9	9	8	8	9	9	10	8	8	8
239	9	7	23	23	11	10	-	18	18	13	8	7	9	11	4
Mean	5.4	6.4	12.7	11.6	9.7	5.4	5.8	8.1	5.9	7.5	4.6	6.0	7.0	5.7	5.1
St. Dev.	2.4	3.1	7.7	7.3	3.4	2.8	2.0	5.7	1.9	3.3	2.9	3.2	2.3	2.6	2.2
Diff. Pre 50			7.3	6.2	4.2			2.7	0.5	2.1			2.4	1.1	0.5
Diff. Pre 20			6.3	5.2	3.3			2.3	0.1	1.7			1.0	-0.3	-0.9

Table II: Relaxation Scores (-8 to +32, Where +32 is Maximum Relaxation Score) on a 10-Item Questionnaire: Alcohol (0.5 and 1.0 ml/kg) and Placebo. Eight Subjects.

	MEDIUM-HIGH DOSE				LOW DOSE				PLACEBO			
	Pre 50	Post 5	Post 80	Post 150	Pre 50	Post 5	Post 80	Post 150	Pre 50	Post 5	Post 80	Post 150
ALCOHOL												
IOP (mm Hg)	12.3	12.4	11.5	11.9	12.4	12.2	12.1	12.5	12.2	12.3	12.3	12.6
Pulse Rate (beats/min)	76.5	80.5	80.0	80.0	72.0	74.5	70.0	72.1	73.0	74.5	67.8	69.3
High Rating (0 to 100)	0	46.9	33.8	13.1	0	21.5	10.6	2.5	0	10.6	1.9	0
Relaxation Scale (-8 to 32)	5.4	12.7	11.6	9.7	5.4	8.1	5.9	7.5	4.6	7.0	5.7	5.1
MARIJUANA												
IOP (mm Hg)	12.4	11.2	9.9	11.1	12.1	11.5	11.3	11.4	12.2	12.3	12.3	12.6
Pulse Rate (beats/min)	68.9	95.0	73.0	73.8	74.0	90.4	77.8	73.5	73.0	74.5	67.8	69.3
High Rating (0 to 100)	0	59.4	37.5	18.1	0	45.6	34.4	13.6	0	10.6	1.9	0
Relaxation Scale (-8 to 32)	4.1	12.1	13.1	10.7	5.0	13.4	12.6	11.1	4.6	7.0	5.7	5.1

Table III: Time Course of Intraocular Pressure (mm Hg), Pulse Rate (Beats/Min), High Rating (0 to 100), and Relaxation Scale (-8 to +32) of the Group (8 Subjects) for Alcohol (0.5 and 1.0 ml/kg), Marijuana (8 and 15 mg THC) and Placebo.

SUBJECT	MARIJUANA 22 mg THC								MARIJUANA PLACEBO*							
	Pre 50	Pre 20	Post 5	Post 30	Post 80	Post 120	Post 180	Post 240	Pre 50	Pre 20	Post 5	Post 30	Post 80	Post 120	Post 180	Post 240
127	11.0	13.2	10.6	9.2	11.0	10.3	9.8	10.0	10.0	12.3	12.4	10.0	12.4	12.0	9.7	-
128	12.0	11.3	10.4	9.0	7.7	9.0	11.9	-	13.3	12.7	14.7	12.7	11.0	9.3	11.0	-
129	15.3	16.6	14.6	15.1	13.2	13.4	13.6	14.0	17.0	-	15.8	14.6	14.8	15.0	14.0	15.0
203	14.5	13.6	12.1	11.0	10.6	11.0	12.8	11.4	12.7	13.3	13.2	13.4	14.0	13.4	13.2	13.2
221	13.0	-	10.6	9.6	8.2	9.2	9.4	3.8	9.1	9.6	9.6	9.6	9.7	9.3	11.9	-
222	9.4	10.3	9.0	7.4	6.8	6.0	8.4	7.4	8.2	-	7.4	8.6	8.4	8.0	7.2	6.8
Mean	12.53	13.00	11.22	10.22	9.58	9.32	10.98	10.52	11.72	11.98	12.18	11.48	11.72	11.17	11.17	11.67
St. Dev.	2.20	2.43	1.93	2.66	2.42	2.45	2.08	2.42	3.27	1.64	3.16	2.41	2.48	2.73	2.47	4.31
Diff. Pre 50			-1.31	-2.31	-2.95	-2.71	-1.55	-2.01			0.46	-0.24	0.00	-0.55	-0.55	-0.05
% Diff.			-10.5	-18.4	-23.5	-21.6	-12.4	-16.0			3.9	-2.0	0.00	-4.7	-4.7	-0.4
Diff. Pre 20			-1.78	-2.78	-3.42	-3.18	-2.02	-2.48			0.20	-0.50	-0.26	-0.81	-0.81	-0.31
% Diff.			-13.7	-21.4	-26.3	-24.5	-15.5	-19.1			1.7	-4.2	-2.2	-6.8	-6.8	-2.6

*Placebo data same as in following Table.

Table IV: Intraocular Pressure (mm Hg): Marijuana (22 mg THC) and Placebo. Minus Indicates Relative Drop in IOP for Group (6 Subjects) Compared to Pre Level.

SUBJECT	MARIJUANA 12 mg THC								MARIJUANA PLACEBO*							
	Pre 50	Pre 20	Post 5	Post 30	Post 120	Post 180	Post 240		Pre 50	Pre 20	Post 5	Post 30	Post 80	Post 120	Post 180	Post 240
127	11.2	12.2	12.0	11.5	12.0	10.7	11.5	-	10.0	12.3	12.4	10.0	12.4	12.0	9.7	-
128	-	11.8	12.2	8.8	8.4	9.4	9.6	-	13.3	12.7	14.7	12.7	11.0	9.3	11.0	-
129	16.0	16.4	15.4	14.0	14.2	14.6	12.0	12.0	17.0	-	15.8	14.6	14.8	15.0	14.0	15.0
203	14.3	14.2	13.6	12.2	14.8	13.4	12.0	14.3	12.7	13.3	13.2	13.4	14.0	13.4	13.2	13.2
221	11.8	10.0	10.6	8.4	8.9	9.3	7.8	7.9	9.1	9.6	9.6	9.6	9.7	9.3	11.9	-
222	8.0	8.2	7.6	6.4	7.0	6.4	6.6	7.4	8.2	-	7.4	8.6	8.4	8.0	7.2	6.8
Mean	12.26	12.13	11.90	10.22	10.88	10.63	9.92	10.4	11.72	11.98	12.18	11.48	11.72	11.17	11.17	11.67
St. Dev.	3.07	2.92	2.66	2.82	3.25	2.99	2.31	3.32	3.27	1.64	3.16	2.41	2.48	2.73	2.47	4.31
Diff. Pre 50			-0.36	-2.04	-1.38	-1.63	-2.34	-1.86			0.46	-0.24	0.00	-0.55	-0.55	-0.05
% Diff.			-2.9	-16.6	-11.3	-13.3	-19.1	-15.2			3.9	-2.0	0.00	-4.7	-4.7	-0.4
Diff. Pre 20			-0.23	-1.91	-1.25	-1.50	-2.21	-1.73			0.20	-0.50	-0.26	-0.81	-0.81	-0.31
% Diff.			-1.9	-15.7	-10.3	-12.4	-18.2	-14.3			1.7	-4.2	-2.2	-6.8	-6.8	-2.6

*Placebo data same as in preceding Table.

Table V: Intraocular Pressure (mm Hg): Marijuana (12 mg THC) and Placebo. Minus Indicates Group (6 Subjects) Drop in IOP Compare to Pre Level.

SUBJECT	MARIJUANA 15 mg THC					MARIJUANA 8 mg THC					MARIJUANA PLACEBO				
	Pre 50	Pre 20	Post 5	Post 80	Post 150	Pre 50	Pre 20	Post 5	Post 80	Post 150	Pre 50	Pre 20	Post 5	Post 80	Post 150
127	11.4	11.0	10.5	10.1	12.0	11.5	12.0	11.5	-	12.0	11.2	-	11.4	12.0	13.2
128	11.2	13.5	10.8	10.3	13.3	9.3	11.6	10.9	11.0	12.0	11.4	-	11.4	13.6	12.0
134	15.2	15.6	14.4	-	13.1	14.5	12.1	14.3	14.0	14.2	15.4	15.2	16.6	14.2	15.3
214	15.0	-	12.2	11.0	10.4	14.0	15.0	11.0	10.8	11.6	13.9	14.4	14.2	13.6	14.6
221	10.0	10.3	10.0	7.8	9.1	10.0	10.7	10.1	8.6	7.3	12.0	-	9.7	9.0	9.6
222	10.6	9.6	8.0	7.7	8.0	9.6	9.3	9.6	10.0	9.5	9.3	-	9.0	8.8	8.0
223	14.0	15.3	14.3	12.8	13.3	16.0	-	13.6	13.6	13.8	16.2	16.0	15.2	16.2	16.4
239	12.0	11.0	9.4	9.3	9.6	11.5	12.0	10.9	11.3	10.8	8.4	10.4	10.8	11.0	11.4
Mean	12.43	12.41	11.20	9.86	11.10	12.05	11.81	11.49	11.33	11.41	12.23	14.00	12.29	12.30	12.56
St. Dev.	2.33	2.38	2.28	1.80	2.10	2.50	1.73	1.64	1.91	2.23	2.77	2.49	2.73	2.59	2.88
Diff. Pre 50			-1.23	-2.57	-1.33			-0.56	-0.72	-0.64			0.06	0.07	0.33
% Diff.			-9.9	-20.7	-10.7			-4.6	-6.0	-5.3			0.5	0.6	2.7
Diff. Pre 20			-1.21	-2.35	-1.31			-0.32	-0.48	-0.40			-1.71	-1.70	-1.44
% Diff.			-9.8	-20.5	-10.6			-2.7	-4.1	-3.4			-12.2	-12.1	-10.3

Table VI: Intraocular Pressure (mm Hg): Marijuana (8 and 15 mg THC and Placebo. Minus Indicates Group (8 Subjects) Drop in IOP Compared to Pre Level.

By plotting the mean IOP drop at 80 min as a function of marijuana dosage (Fig. 4), a dose relationship curve is established. Although the sample size is small (6 to 8 subjects at each dose level), the regularity of the data points is impressive. In part, this result may be due to the sample being made up of subjects who are only light to moderate users of marijuana. Flom *et al.* (1974) found that subjects who used marijuana 4 times a week or more and stayed "stoned" all day on about half the smoking occasions exhibited little or no IOP drop 80 min after an experimental dose of 12 mg THC. In other words, there appears to be a tolerance to the IOP effects produced by marijuana. For the subjects in the present sample, the post-80 IOP drop increased from about 0.7 mm Hg for the 8 mg THC dose to about 3.0 mm Hg for the 22 mg THC dose. These pressure drops amount to about 6% and 24% respectively.

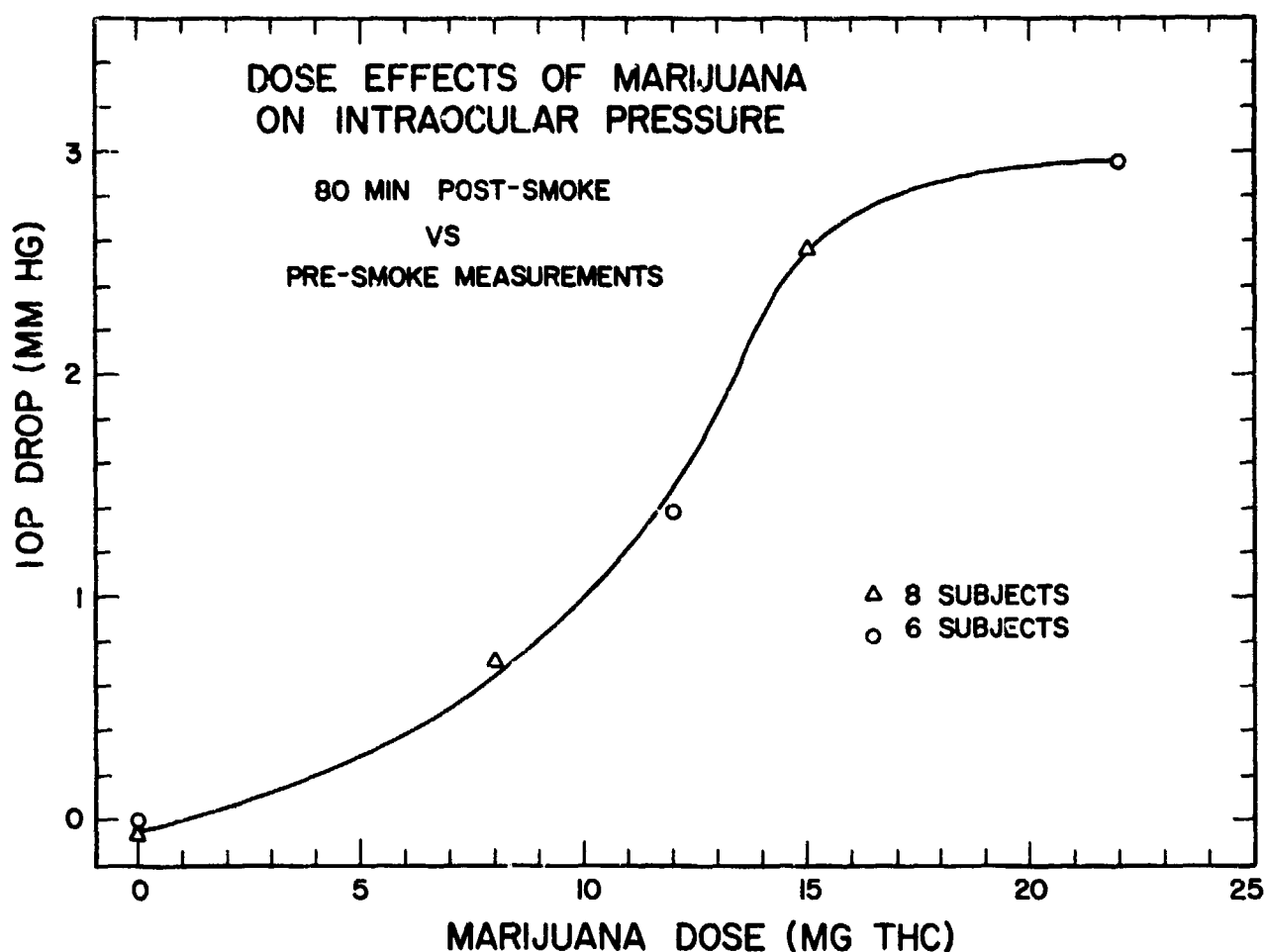


Fig. 4: IOP drop as a function of marijuana dose in two experiments. Marijuana (8 and 15 mg THC) and placebo for 8 subjects; marijuana (12 and 22 mg THC) and placebo for 6 subjects. Four subjects were common to both experiments.

Flom *et al.* (1974) found that smoking marijuana (12 mg THC) reduced IOP only for those of 15 subjects who experienced a substantial "high" and a state of peaceful relaxation from the experimental dose, and who smoked fewer than 4 marijuana cigarettes a week. In the present sample of 8 subjects, the same results were obtained for the 15 mg THC dose except that the relationships fail to reach statistical significance (Spearman rank correlation between IOP drop and "high" is -0.59 , $p > 0.05$; between IOP drop and relaxation r_s is -0.58 , $p > 0.05$). Relaxation scores for individual subjects after smoking marijuana are presented in Table VII. Mean values for other related variables are presented in Table III.

SUBJECT	MARIJUANA 15 mg THC					MARIJUANA 3 mg THC					MARIJUANA PLACEBO				
	Pre 50	Pre 20	Post 5	Post 30	Post 150	Pre 50	Pre 20	Post 5	Post 30	Post 150	Pre 50	Pre 20	Post 5	Post 30	Post 150
127	4	9	13	14	8	6	9	12	11	-	6	-	10	6	6
128	4	4	18	11	12	4	4	20	18	13	4	-	4	4	4
134	3	3	6	4	3	3	3	4	5	3	3	3	4	3	3
214	3	-	3	17	14	0	3	8	11	13	4	4	-	4	3
221	2	6	1	4	5	4	3	10	3	13	3	-	7	4	-
222	5	5	23	22	16	4	4	16	14	17	0	-	7	6	8
223	6	7	9	9	7	9	-	12	9	8	9	10	8	8	8
239	16	21	24	24	17	10	12	25	30	11	8	7	9	11	4
Mean	4.1	7.8	12.1	13.1	10.7	5.0	5.4	13.4	12.6	11.1	4.6	6.0	7.0	5.7	5.1
St. Dev.	1.4	6.1	8.8	7.6	4.8	3.2	3.6	6.7	8.5	4.4	2.9	3.2	2.3	2.6	2.2
Diff. Pre 50			8.0	9.0	6.6			8.4	7.6	6.1			2.4	1.1	0.5
Diff. Pre 20			4.3	5.3	2.9			8.0	7.2	5.7			1.0	-0.3	-0.9

Table VII. Relaxation Scores (-8 to +32, Where +32 is Greatest Relaxation) on 10-Item Questionnaire: Marijuana (8 and 15 mg THC) and Placebo for 8 Subjects.

B. Heterophoria

1. Procedure

Heterophoria is a latent deviation of the eyes that becomes manifest when binocular fused vision is disrupted. Heterophoria reflects the oculomotor imbalance. The sum of all tonic inputs, both supra- and infra-nuclear, which contribute to extraocular muscle tonus is reflected in the heterophoria (phoria). Phorias can be changed by certain drugs, peripherally by homatropine and systemically by barbiturates, alcohol, and anoxia (Ogle, 1967).

The automated 10-sec phoria device developed by OSG enabled us to measure heterophoria objectively at optical infinity (targets physically at 40 cm). Subjects look into a box through two lens apertures and fixate a small light; the fixation field is divided by a septum. The amplitude of eye movements made to a short series of alternate left and right eye fixation lights is used by the device to calculate the heterophoria. The device displays the heterophoria measurement in prism diopters on a digital voltmeter.

Distance heterophoria was determined by the subjective clinical technique of Von Graefe. In this test the subject fixates a small target at 6 m with the right eye. A 6Δ dissociation prism is placed base down in a trial frame in front of the left eye. The left eye is covered with a paddle which is intermittently removed to enable the subject to report on the alignment of the 2 images of the target. A bracketing technique with appropriate lateral prisms was used until the subject reported horizontal alignment of the vertically displaced images.

Phoria was measured prior to the treatment (drinking or smoking) using both measurement techniques. After alcohol ingestion, each subject's phoria was measured at 50, 110, and 170 min post-drug. Subjects receiving marijuana were tested at 6 different time intervals after smoking, covering a period of 3 hr post-drug. Eight subjects received an alcohol dose of 1.0 ml/kg and an alcohol placebo in a cross-over design. Three subjects received 2 doses of 22 mg THC marijuana and a marijuana placebo in a cross-over design.

2. Results and Comments

In our 1973 Annual Report, we described heterophoria experiments with alcohol and marijuana. Heterophoria was measured objectively by a 1 min test involving the detection of eye movements. The absence of an eye movement to a given stimulus presentation indicated the phoria position (see 1973 Report for details of the test). Although the stimuli were at optical infinity, they were physically only 10 cm from the eye plane. The resultant phoria measure thus contained a proximal convergence (eso-phoria tendency) component. Fourteen subjects smoking 12 mg THC, and 5 subjects with blood alcohol levels of approximately 0.07%, showed no consistent change

in phoria. This result was contrary to reports in the literature of esophoric shift for distance viewing for relatively large doses (0.05 to 0.15%) of alcohol (Brecher *et al.*, 1972). In an attempt to explain the discrepancy, we speculated that an esophoric shift may have been masked by a reduction in proximal (or instrument) vergence in our experiments. We proposed that further experiments be done to measure phoria both at physical distance and optical distance.

SUBJECT	ALCOHOL 1.0 ml/kg				ALCOHOL PLACEBO				ALCOHOL MINUS PLACEBO			
	Pre 20	Post 50	Post 110	Post 170	Pre 20	Post 50	Post 110	Post 170	Pre 20	Post 50	Post 110	Post 170
127	0	1.0	4.0	4.0	-1.0	-1.0	-1.0	-0.8	1.0	2.0	5.0	4.8
128	1.0	2.0	2.0	1.5	2.0	1.5	1.5	1.5	-1.0	0.5	0.5	0
129	-1.5	0	2.0	0.5	-0.5	-0.5	-0.5	-1.5	-1.0	0.5	2.5	2.0
130	0	4.0	4.5	3.0	-1.5	-1.5	-2.0	-1.5	1.5	5.5	6.5	4.5
131	-1.5	4.0	6.0	1.5	-2.0	-1.5	-1.5	-1.5	0.5	5.5	7.5	3.0
132	2.0	6.0	4.0	4.0	0	0	0	0	2.0	6.0	4.0	4.0
134	-1.5	2.0	2.5	2.5	-0.5	-1.5	-1.5	-1.5	-1.0	3.5	4.0	4.0
135	-2.0	0	2.0	0.5	-1.5	-1.8	-2.5	-2.5	-0.5	1.8	4.5	3.0
Mean	-0.4	2.4	3.4	2.2	-0.6	-0.8	-0.9	-1.0	0.2	3.2	4.3	3.2
St. Dev.	1.4	2.1	1.5	1.4	1.3	1.1	1.3	1.2	1.2	2.3	2.2	1.6
Diff. Pre 20		2.8	3.8	2.6		-0.2	-0.3	-0.4		3.0	4.1	3.0

Table VIII. Heterophoria (Prism Diopters) by Subjective Method of Von Graefe (for 6 m Viewing Distance): Alcohol (1.0 ml/kg) and Placebo for 8 Subjects. Esophoria ("+"), Exophoria ("-"). Alcohol Minus Placebo Shows Relative Heterophoria Shift.

a. Alcohol

The effects of 1.0 ml/kg alcohol on the subjectively measured phoria at 6 m is shown in Table VIII. All 8 subjects showed an esophoric shift, amounting to a mean of 3.8Δ for the group 2 hr after drinking. The same subjects had a small mean exophoric shift (-0.3Δ) at a comparable time after drinking the alcohol placebo. The alcohol and placebo results for the group are illustrated in Fig. 5 and indicate a peak in esophoric shift at 2 hrs with a subsequent slow return towards the pre-treatment level. The mean pre-drink values for the placebo and alcohol treatments have been equated. The mean blood alcohol level for the group follows a similar time course, suggesting a relatively linear relationship between blood alcohol level and esophoric shift.

This esophoric shift is also reflected in the automated phoria measures at the 40 cm (and optical infinity) distance. Here, the mean esophoric shift is 2.5Δ at 2 hr after drinking (Table IX). The same subjects show a small mean exophoric shift (-0.5Δ) at a comparable time after drinking the alcohol placebo. The mean proximal (or instrument) vergence is 2.6Δ (determined by comparing the pre-drink phorias measured by the two methods). It is apparent that half ($3.8\Delta - 2.5\Delta = 1.3\Delta$) of the proximal vergence is reduced by alcohol. One phoria value (underlined in Table IX) is unusually large and influences the mean disproportionately. If it is omitted in the calculation of the mean phoria, the group phoria is 3.2Δ ; this creates an esophoric shift of 1.0Δ at the 40 cm (and optical infinity) distance. By this analysis, all of the proximal vergence manifested in the automated phoria device masks much of the actual shift in distance phoria. If one assumes a 4Δ esophoric shift, then a reduction of 4Δ of proximal vergence would neutralize the distance phoria shift in testing devices where proximal vergence is manifested. In our 1973 report, only a small mean esophoric shift was reported for our 5 subjects; 2 of the subjects actually showed an exophoric shift 1 hr after drinking. We used a phoria device with stimuli at 10 cm from the eye plane and with the proximal vergence being between 4 and 6Δ . It is likely that esophoric shifts occurred in those 5 subjects, but were masked by an alcohol-induced reduction in the proximal vergence. Placebo changes were determined for each subject; consequently, a direct measure of the drug effect on individuals can be made by comparing this change to the drug change. These relative shifts are also displayed in Tables VIII and IX.

The esophoric shift with alcohol seen in our experiments is consistent with other reports (e.g., Brecher *et al.*, 1955). However, we are unaware of any reports of alcohol reducing the proximal vergence component.

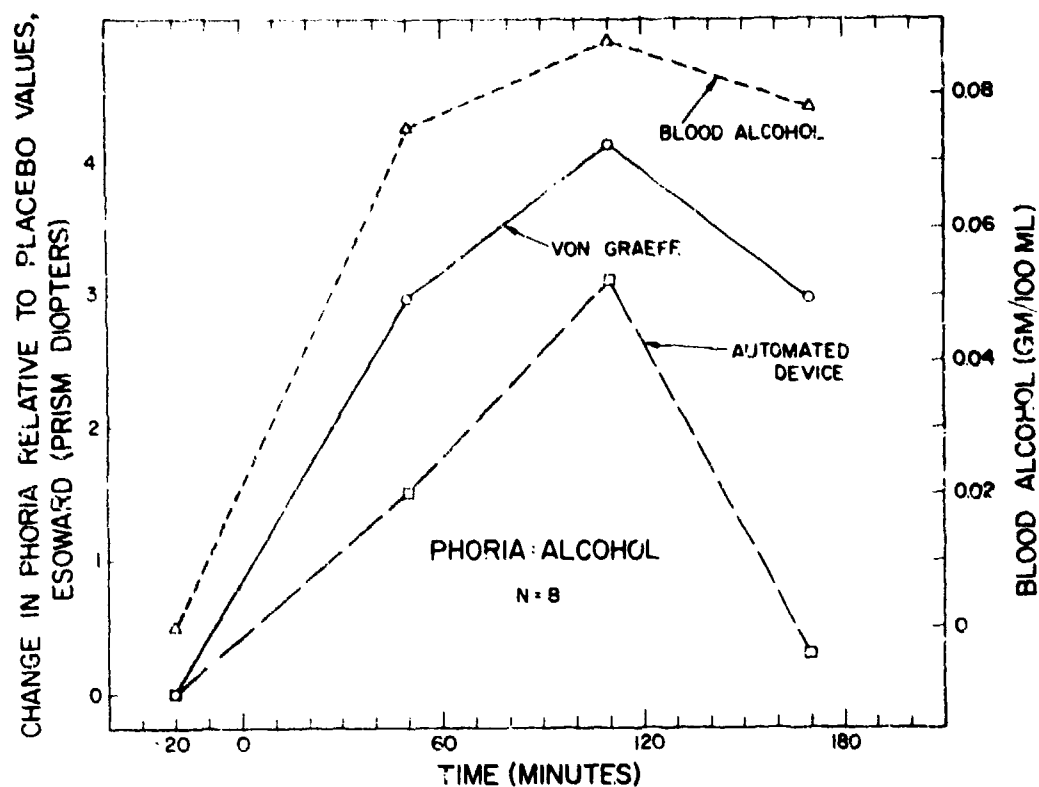


Fig. 5: Relative change in heterophoria (prism diopters) for 6 m viewing distance (subjective method of Von Graefe) and optical infinity at 40 cm viewing distance (objective method of automated phoria device) as a function of time after drinking (1.0 ml/kg alcohol and placebo). Eight subjects. Group blood alcohol level (gm/100 ml) indicated on same Fig.

SUBJECT	ALCOHOL 1.0 ml/kg				ALCOHOL PLACEBO				ALCOHOL MINUS PLACEBO			
	Pre 20	Post 50	Post 110	Post 170	Pre 20	Post 50	Post 110	Post 170	Pre 20	Post 50	Post 110	Post 170
127	2.1	4.6	3.1	3.2	-	-	-	-	-	-	-	-
128	-	-	-	-	5.2	2.6	2.7	3.3	-	-	-	-
129	2.1	1.6	3.0	4.5	-1.8	-0.4	-0.3	0.7	3.9	2.0	3.3	3.8
130	2.3	4.5	3.9	2.8	-	-	-	-	-	-	-	-
131	1.9	6.3	13.9	3.2	1.5	1.3	1.6	2.1	0.4	5.0	12.3	1.1
132	4.8	4.2	2.3	3.8	3.2	0.7	2.0	3.3	1.6	3.5	0.3	0.5
134	2.9	4.1	6.1	5.4	3.1	2.5	2.2	3.2	-0.2	1.6	3.9	2.2
135	-0.5	2.3	0.8	-0.9	0.3	1.7	0.2	0.2	-0.8	0.6	0.6	-1.1
Mean	2.2	3.9	4.7	3.1	1.9	1.4	1.4	2.1	1.0	2.5	4.1	1.3
St. Dev.	1.6	1.6	4.4	2.0	2.5	1.1	1.2	1.4	1.9	1.7	4.9	1.8
Diff. Pre 20		1.7	2.5	0.9		-0.5	-0.5	0.2		1.5	3.1	0.3

Table IX. Heterophoria (Prism Diopters) by Automated Phoria Device (Optical Infinity at 40 cm Viewing Distance): Alcohol (1.0 ml/kg) and Placebo for 8 Subjects. Esophoria ("+"), Exophoria ("−").

b. Marijuana

The maximum mean distance esophoric shift with the Von Graefe method for 3 subjects is 2Δ at 70 min after smoking 12 mg THC (Table X). This measure is free of proximal vergence. At the same time, the mean esophoric shift for the automated phoria device is about 0.5Δ. With marijuana, as with alcohol, there seems to be reduction in proximal vergence. At 90 min post-marijuana, the reduction in proximal vergence from pre-drug controls is 2.4Δ.

Although more subjects will be needed to confirm the results from these 3 subjects, it is already obvious that the apparent lack of mean phoria change in the 14 subjects of last year's report may only reflect the counter-balancing of a distance esophoric shift and a reduction of proximal vergence. A distance esophoric shift has been reported (Moskowitz *et al.*, 1972) following smoking of approximately 14 mg THC. However, change in proximal vergence has not previously been reported for marijuana smoking.

PHORIA TEST	MARIJUANA (22 mg THC)							MARIJUANA PLACEBO						
	Pre 20	Post 10	Post 35	Post 70	Post 90	Post 130	Post 180	Pre 20	Post 10	Post 35	Post 70	Post 90	Post 130	Post 180
Von Graefe	0.25	0.92	1.30	2.25	1.96	1.71	1.46	0.30	0.58	0.75	0.30	0.50	-0.20	0.90
Objective Device	4.08	5.13	4.50	4.63	3.42	3.98	3.53	1.53	2.30	3.00	2.10	2.50	2.00	4.10
Diff. Pre 20		0.67	1.05	2.00	1.71	1.46	1.21		0.28	0.45	0.50	0.20	-0.50	0.60
Proximal Vergence	3.83	4.21	3.20	2.38	1.46	2.27	2.07	1.23	1.72	2.25	1.30	2.00	2.20	3.20

Table X. Group Heterophoria (Prism Diopters) by Von Graefe Method (for 6 m Viewing Distance) and Automated Phoria Device (Optical Infinity at 40 cm Viewing Distance): Marijuana (22 mg THC) and Placebo for 3 Subjects. Esophoria ("+"), Exophoria ("-").

C. Optokinetic Nystagmus

1. Procedure

The onset of optokinetic nystagmus (OKN) was used as a measure of the objective glare recovery time. The details of this test and the role of OKN are discussed in Section F (Glare Recovery) and in a report by Jampolsky *et al.* (1973). OKN was recorded for 30 sec using the moving vertical stripes in the glare recovery box as the stimulus. Recordings of eye movements were obtained with an infrared electro-optical device and were displayed on a Beckman polygraph. Recordings were made at the end of each glare recovery measurement on 9 subjects who were given an alcohol dose of 1.0 ml/kg.

2. Results and Comments

Qualitative analysis of the records was performed. Analysis suggests that after drinking alcohol, the frequency of OKN decreased, the size of the saccadic component decreased, and the OKN became less regular.

Two basic explanations can account for the observed changes in OKN. If the relationship between saccadic velocity and saccadic amplitude is assumed to be constant (Hyde, 1959) during the drug state, then the subjects must have moved their eyes less often or with slower pursuit velocity to account for the observed decrease in saccadic frequency. A decrease in excursion made before executing a saccadic return would explain the smaller size of saccades found in the drug state.

However, it is known that other drugs such as diazepam (Valium) can alter the normal relationship between saccadic velocity and saccadic amplitude (Aschoff, 1968). Under the assumption that alcohol alters this relationship, the observed alcohol-induced changes in OKN can be explained by full amplitude excursions with reduced velocity of the smooth pursuit component, as well as by reduced saccadic velocity.

D. Sinusoidal Pursuit Eye Movements: Maximum Velocity

1. Procedure

The subject views an oscilloscope screen at a distance of 80 cm; a spot on the screen moves horizontally in a sinusoidal motion through an angle of 8 degrees. Frequency of the sinusoidal oscillation increases regularly and automatically from 0.5 Hz to 3.0 Hz over a period of 40 sec. The highest frequency at which the subject can accurately follow the sinusoidally oscillating target was recorded as the endpoint of the test. Eye movements were determined with an electro-optical limbal sensing technique and recorded on a Beckman polygraph.

Quantifying the performance of some subjects was difficult. Some intermittently failed to follow the target, only to regain good eye tracking at higher frequencies. After extensive qualitative examination of all the records, the cutoff frequency was defined as: the stimulus frequency at which the amplitude of the eye movement decreases to less than half of that for the immediately preceding cycle, and amplitude recovery does not occur within 4 stimulus cycles.

Jampolsky *et al.* (1973) noted decrements in the high frequency cutoff for smooth pursuit eye movements after low and moderate doses of alcohol but not after moderate doses of marijuana. This potentially important positive result for alcohol requires confirmation with a larger sample than 5 subjects and with a placebo control. The negative result obtained with marijuana (12 mg THC) needs to be verified for a higher marijuana dose, such as 22 mg THC. The experiments described here had these purposes in mind.

SUBJECT	ALCOHOL 1.0 ml/kg				ALCOHOL PLACEBO				ALCOHOL MINUS PLACEBO			
	Pre 20	Post 50	Post 110	Post 170	Pre 20	Post 50	Post 110	Post 170	Pre 20	Post 50	Post 110	Post 170
127	1.85	1.79	1.51	1.51	2.00	2.08	1.98	2.22	-0.15	-0.29	-0.47	-0.71
128	1.70	1.34	1.63	1.50	1.43	1.43	1.51	1.67	0.27	-0.09	0.12	-0.17
129	1.72	1.56	1.35	1.19	1.47	1.67	1.92	1.56	0.25	-0.11	-0.57	-0.37
130	1.56	1.92	1.06	1.19	1.63	1.75	1.62	1.68	-0.07	0.17	-0.56	-0.49
131	1.72	1.39	1.14	-	1.61	1.73	1.67	1.78	0.11	-0.34	-0.53	-
132	2.0	1.43	1.47	1.56	1.56	1.92	2.00	1.43	0.44	-0.49	-0.47	0.13
133	1.25	0.93	-	-	1.28	1.14	1.28	1.34	-0.03	-0.21	-	-
134	1.78	1.67	1.32	1.42	1.82	1.51	1.85	2.08	-0.04	0.16	0.53	-0.66
135	-	1.25	1.02	1.04	1.85	1.67	1.79	2.08	-	-0.42	-0.77	-1.04
Mean	1.70	1.48	1.31	1.34	1.63	1.66	1.73	1.76	0.1	-0.18	-0.47	-0.47
St. Dev.	0.22	0.30	0.22	0.20	0.23	0.27	0.24	0.31	0.21	0.23	0.26	0.38

Table XI. Maximum Velocity of Sinusoidal Smooth Pursuit Eye Movements (Cutoff Frequency in Hz to a Spot Target of Fixed Amplitude, Increasing Linearly from 0.5 to 3.0 Hz): Alcohol (1.0 ml/kg) and Placebo for 9 Subjects. Alcohol Minus Placebo Values at Each Time Show Relative Eye Movement Performance.

2. Results and Comments

a. Alcohol

Nine subjects were given both alcohol (1.0 ml/kg, producing blood alcohol levels of approximately 0.08%) and alcohol placebo treatments in a cross-over design. Smooth pursuit tracking performance was measured both prior to the treatment and at approximately 1 hr following the treatment. Without exception, tracking performance was reduced for the alcohol condition.

Individual and group results are presented in Table XI. The alcohol-induced performance changes for the group are shown in Fig. 6. Fifty min after alcohol ingestion, smooth eye tracking performance was already reduced. Two hr later, performance was still substantially reduced and blood alcohol levels were still high (about 0.08%). These results confirm those reported by Jampolsky *et al.* (1973) for a smaller sample, and the additional placebo experiments indicate that the changes are specific to the alcohol condition.

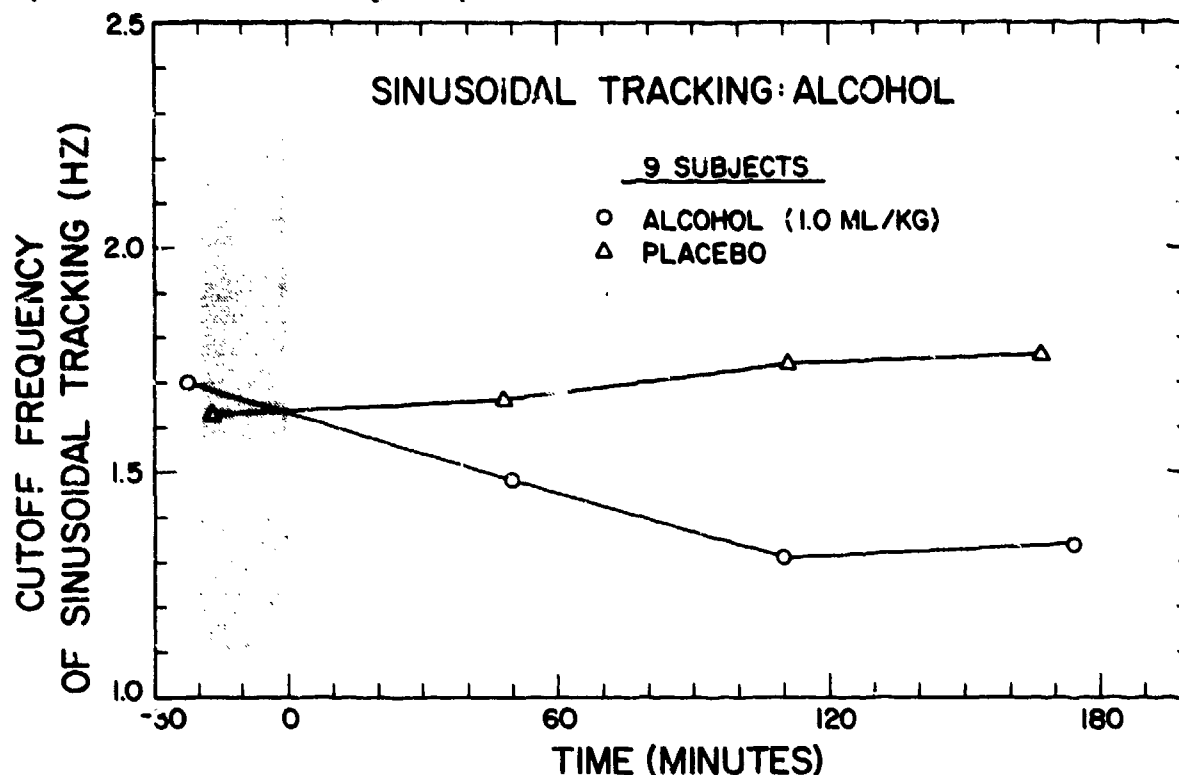


Fig. 6: Time course of effect of alcohol (1.0 ml/kg) and alcohol placebo on sinusoidal eye movement tracking (cutoff frequency in Hz to a spot target of fixed amplitude, increasing linearly from 0.5 to 3.0 Hz). Nine subjects.

SUBJECT	MARIJUANA 22 mg THC							MARIJUANA PLACEBO						
	Pre 20	Post 5	Post 30	Post 60	Post 90	Post 120	Post 180	Pre 20	Post 5	Post 30	Post 60	Post 90	Post 120	Post 180
127	2.08	1.88	2.27	2.18	2.20	2.30	2.00	1.92	2.08	2.18	1.92	2.00	2.17	2.17
127	1.73	1.55	1.26	1.71	1.63	1.34	1.86							
128	1.52	1.70	1.25	1.56	1.39	1.68	1.72	1.67	1.75	1.19	1.05	1.48	1.23	1.78
128	1.54	1.39	1.14	1.56	1.58	1.48	1.51							
129	1.72	1.33	1.56	1.72	1.65	1.66	1.70	1.85	2.07	1.52	1.78	2.04	1.95	1.78
129	1.69	1.65	1.76	1.80	1.65	1.78	1.49							
Mean	1.71	1.58	1.54	1.76	1.68	1.71	1.71	1.81	1.97	1.63	1.58	1.84	1.78	1.91
St. Dev.	0.2	0.2	0.43	0.23	0.27	0.33	0.20	0.13	0.19	0.50	0.47	0.31	0.49	0.23

Table XII. Maximum Velocity of Sinusoidal Smooth Pursuit Eye Movements (Cutoff Frequency in Hz to a Spot Target of Fixed Amplitude, Increasingly Linearly from 0.5 to 3.0 Hz). Marijuana (22 mg THC) and Placebo for 6 Subjects.

b. Marijuana

Three subjects from the alcohol group were also given two separate treatments of 22 mg THC, as well as the marijuana placebo. The cutoff frequencies for each subject and the group are presented in Table XII. The time course of the cutoff frequency is displayed in Fig. 7. The results are consistent with those of Jampolsky *et al.* (1973) for 12mg THC, namely that marijuana does not reduce the maximum velocity of smooth pursuit eye movements.

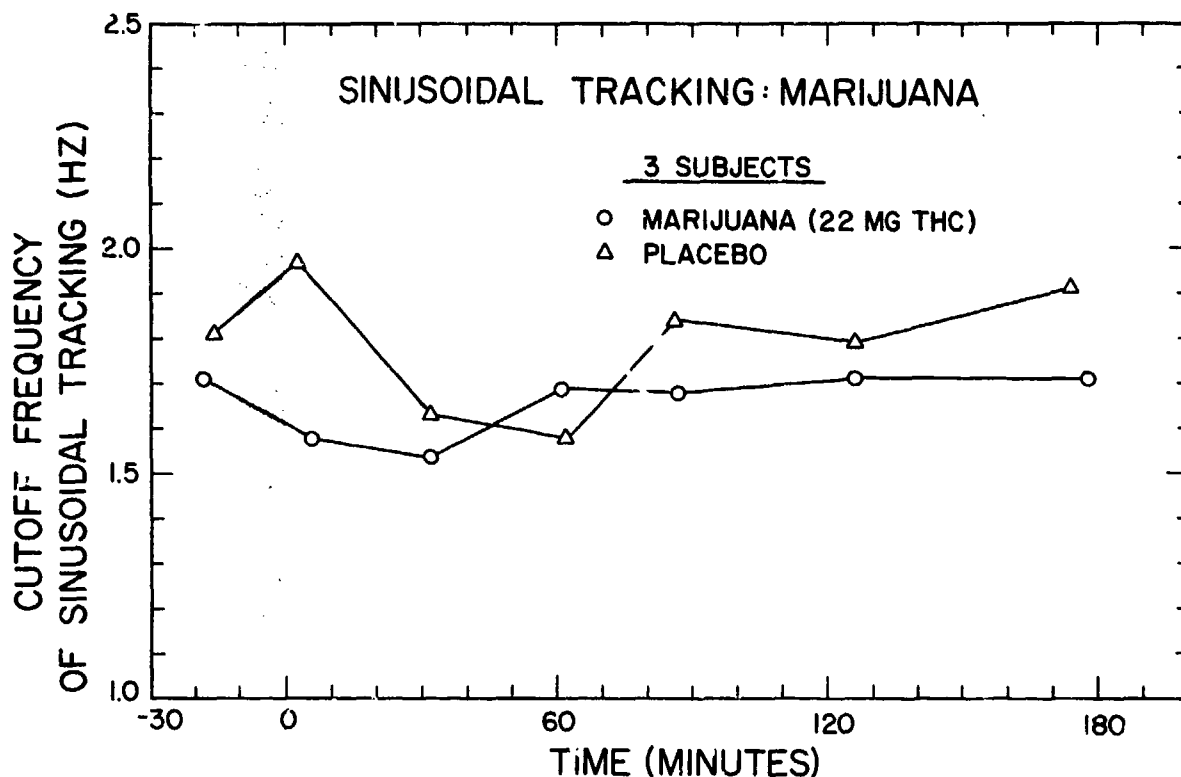


Fig. 7: Time course of effect of marijuana (22 mg THC and placebo) on sinusoidal eye movement tracking (cutoff frequency in Hz to a spot target of fixed amplitude increasing linearly from 0.5 to 3.0 Hz). Three subjects.

E. Sinusoidal Pursuit Eye Movements:
Reduced Information

1. Procedure

The subject is seated 80 cm from an oscilloscope which subtends 8 degrees at his eye; on the oscilloscope X-plates, there is a 0.5 Hz sinusoidal waveform and on the Y-plates a train of 50 msec pulses. Only the upper edge of this pulse train is visible to the subject. The frequency of the pulse train is variable and is set at 10, 5, or 2 Hz to vary the amount of stimulus information presented to the subject. Thus, the subject sees an intermittently present spot moving horizontally back and forth with sinusoidal velocity. The stimulus is visible to the subject 50% of the time for the 10 Hz condition, 25% for the 5 Hz, and 10% for the 2 Hz condition.

Eye movements were determined using an electro-optical limbal sensing technique and recorded on a Beckman polygraph. The eye movement signal was differentiated to show the different phases of the eye movement (i.e., slow pursuit movements and fast saccadic movements). The amplitude of the differentiated signal is a direct measure of the amplitude of the sinusoidal component of the eye position signal.

2. Results and Comments

Less time is spent smoothly tracking when the amplitude and/or frequency of saccadic eye movements increases. The amplitude and frequency of saccadic eye movements are related to the amplitude of the smooth sinusoidal tracking by the expression,

$$A + n\bar{a} = K,$$

where A = amplitude of smooth sinusoidal tracking
 n = number of saccadic eye movements per second
 \bar{a} = average amplitude of the saccadic eye movement
 K = constant

The equation is based on the assumption that eye movements are made to match the stimulus amplitude.

The gain of the eye movement signal is dependent on the position of the electro-optical eye position sensors, head position, etc., and may vary from one measurement session to another. Within a measurement session (including the presentation of all 3 stimulus conditions), there was no change in the gain. Gain changes between sessions were overcome for analysis purposes by normalizing the eye position amplitude signal to 10 (i.e., $K=10$) for each of the 10 Hz stimulus presentations. This normalizing factor was then applied to the differentiated sine amplitude measures for the 10 Hz, 5 Hz, and 2 Hz responses.

a. Alcohol

Smooth eye tracking was reduced after alcohol (1 ml/kg) for all 3 conditions of reduced information, while there was only a slight and inconsistent change for the placebo. This result for 3 subjects is reflected in the relative amplitude of the smooth movements shown in Table XIII and Fig. 8. The progressively decreased smooth tracking is associated with an increase in the number of saccadic eye movements at 5 and especially 10 Hz, suggesting that although smooth tracking performance was reduced there is continued effort by the subjects to follow the stimulus. However, for the 2 Hz condition there seems to be a different strategy associated with the decrease in smooth tracking. Here, the number of saccadic eye movements decreased 45 min after alcohol, suggesting that the subjects made less effort to follow the stimulus, and responded by making intermittent large amplitude saccades.

Although these results are based on only 3 subjects, there is nevertheless a clear trend in the results. Alcohol impairs the smooth tracking performance when the stimulus information is reduced.

			RELATIVE AMPLITUDE OF SMOOTH MOVEMENTS				NUMBER OF SACCADIC EYE MOVEMENTS PER SECOND			
			Pre 20	Post 45	Post 110	Post 170	Pre 20	Post 45	Post 110	Post 170
PLACEBO (N=3)	10 Hz	Mean	5.3	5.0	5.7	8.5	0.9	1.2	1.1	1.3
		St. Dev.	3.8	1.9	3.0	1.7	0	0.3	0.2	0.1
	5 Hz	Mean	6.4	4.2	4.3	6.3	1.3	1.3	1.2	1.6
		St. Dev.	3.6	1.5	0.9	1.6	0.2	0.1	0.2	0.3
	2 Hz	Mean	4.0	2.1	2.5	4.4	1.4	1.5	1.5	1.5
		St. Dev.	2.6	0.8	0.9	1.9	0.5	0.7	0.2	0.2
ALCOHOL 1 ml/kg (N=3)	10 Hz	Mean	7.7	6.7	4.3	2.8	0.9	1.4	1.6	1.9
		St. Dev.	0.6	2.5	0.1	1.2	0.4	0.5	0.6	0.6
	5 Hz	Mean	6.7	5.8	3.2	2.2	1.3	1.5	1.6	1.6
		St. Dev.	0.7	1.0	1.3	1.2	0.2	0.5	0.3	0.7
	2 Hz	Mean	3.8	2.6	1.2	1.6	1.5	1.2	1.5	1.6
		St. Dev.	1.4	0.9	0.1	0.9	0.3	0.7	0.7	0.9

Table XIII. Alcohol (1.0 ml/kg) Effects on Eye Tracking of Sinusoidally Moving Spot (0.5 Hz) Pulsed for 50 msec at 10, 5, and 2 Times/Sec for Group (3 Subjects): Relative Amplitude (Arbitrary Units) of Smooth Movement and Saccadic Frequency (Saccades/Sec).

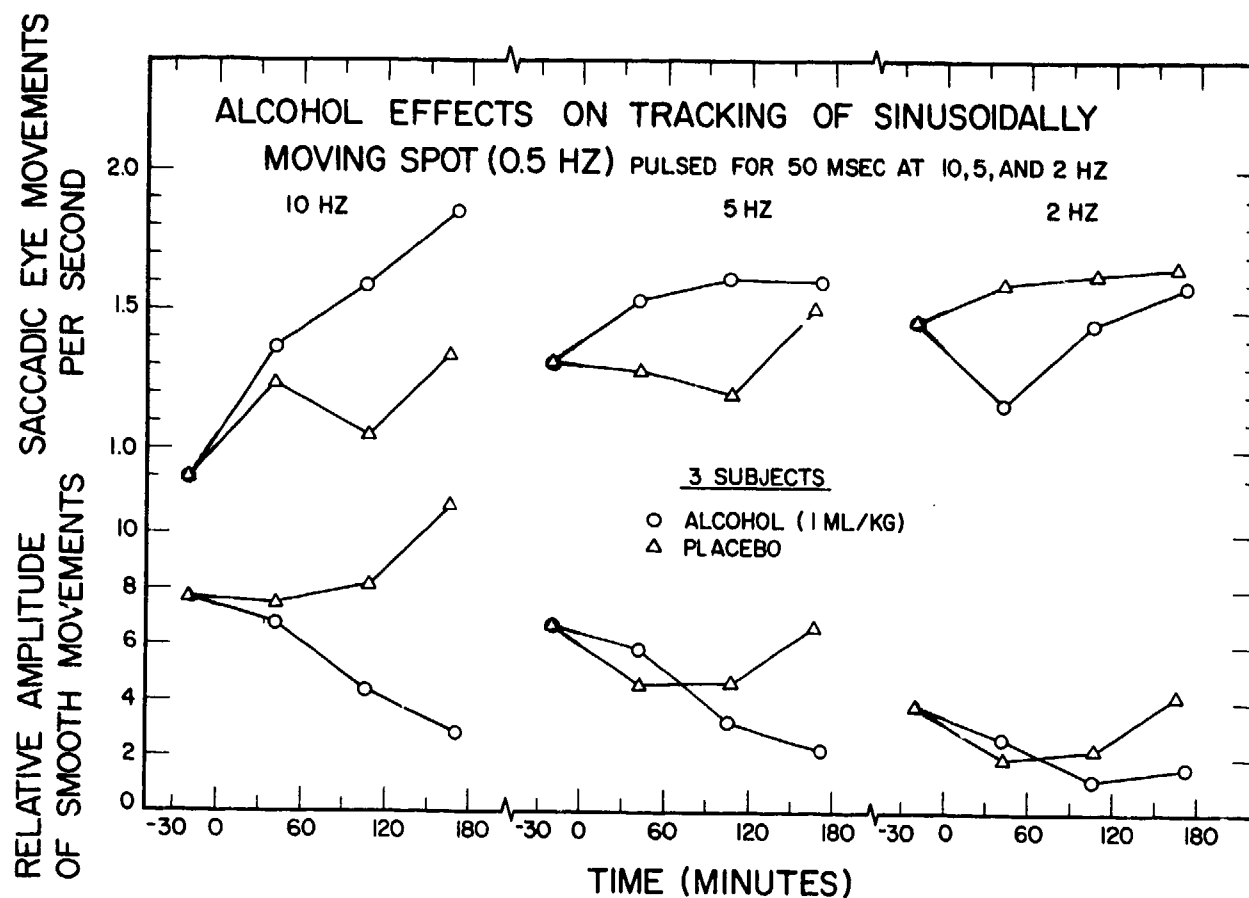


Fig. 8: Time Course of alcohol (1ml/kg) and placebo effects on eye tracking of sinusoidally moving spot (0.5 Hz) pulsed for 50 msec at 10, 5, and 2 times/sec for group (3 subjects).

b. Marijuana

Three of the subjects studied with alcohol comprised the sample for the marijuana experiment (22 mg THC and marijuana placebo). Under conditions of reduced stimulus information, smooth eye tracking performance was reduced (Table XIV and Fig. 9).

For all 3 stimulus conditions, marijuana produced a slight but immediate and sustained decrease in smooth tracking performance which is not seen for the marijuana placebo. For the higher information stimuli (10 Hz, 5 Hz), there is an initial unsustained decrease in the number of saccadic eye movements suggesting that the subjects followed poorly and made relatively infrequent eye movements during the earliest post-smoking tests. Over a period of 3 hr after smoking, the smooth tracking performance remained reduced but at a fairly steady level. During that time there was an increase in the number of saccadic eye movements, suggesting an increased ability to follow the target without any increase in smooth tracking eye movements.

A somewhat different pattern of response is evident for the 2 Hz stimulus condition. Although smooth tracking performance was reduced by marijuana, it was *not* accompanied by a decrease in the number of saccadic eye movements after smoking marijuana.

A decrease in tracking performance as found in these experiments may be significant in everyday situations. The tracking of low information stimuli (e.g., low contrast objects, or objects moving behind intervening structures such as trees) may become increasingly difficult for personnel after drinking alcohol or smoking marijuana. The result could be a loss of the target of interest. In general, the performance after alcohol might be expected to be worse than after smoking marijuana, but the dose relationship has yet to be established.

		RELATIVE AMPLITUDE OF SMOOTH MOVEMENTS							NUMBER OF SACCADIC EYE MOVEMENTS PER SECOND						
		Pre 20	Post 5	Post 30	Post 60	Post 85	Post 125	Post 180	Pre 20	Post 5	Post 30	Post 60	Post 85	Post 125	Post 180
PLACEBO (N=5)															
10 Hz	Mean	6.1	6.2	5.7	5.4	6.4	6.1	6.0	1.4	1.5	1.7	1.6	1.6	1.3	1.5
	St. Dev.	1.6	2.0	2.1	2.0	1.7	2.1	2.6	0.5	0.3	0.3	0.7	0.5	0.2	0.5
5 Hz	Mean	5.9	6.5	4.3	5.4	5.9	4.3	5.6	1.6	1.5	1.5	1.8	1.6	1.6	1.9
	St. Dev.	1.9	1.0	2.4	2.5	2.1	1.7	2.2	0.4	0.2	0.8	0.6	0.3	0	0.4
2 Hz	Mean	2.4	1.7	1.9	2.1	2.5	1.6	1.7	1.8	1.8	2.1	1.8	1.9	2.2	2.1
	St. Dev.	0.7	0.8	0.2	0.1	1.5	0.3	0.5	0.3	0.5	0.4	0.1	0.4	0.1	0.3
MARIJUANA 22 mg THC (N=3)															
10 Hz	Mean	6.0	4.7	4.4	4.5	4.4	4.3	3.9	1.3	1.0	1.3	1.6	1.6	1.5	1.6
	St. Dev.	1.7	1.6	1.5	1.1	1.8	2.0	2.0	0.6	0.3	0.4	0.5	0.3	0.3	0.3
5 Hz	Mean	6.0	3.8	3.7	3.8	4.4	3.1	2.7	1.6	1.3	1.4	1.5	1.6	1.5	1.7
	St. Dev.	2.3	1.2	1.6	1.1	1.5	1.2	0.5	0.4	0.4	0.3	0.3	0.3	0.3	0.3
2 Hz	Mean	2.8	1.7	1.8	1.7	1.6	1.3	1.0	1.4	1.6	1.7	1.8	1.7	1.8	1.7
	St. Dev.	0.9	0.9	1.0	1.2	0.6	0.7	0.7	0.5	0.7	0.4	0.4	0.4	0.2	0.2

Table XIV. Marijuana (22 mg THC) Effects on Eye Tracking of Sinusoidally Moving Spot (0.5 Hz) Pulsed for 50 msec at 10, 5, and 2 Times/Sec for Group (3 Subjects): Relative Amplitude (Arbitrary Units) of Smooth Movement and Saccadic Frequency (Saccades/Sec).

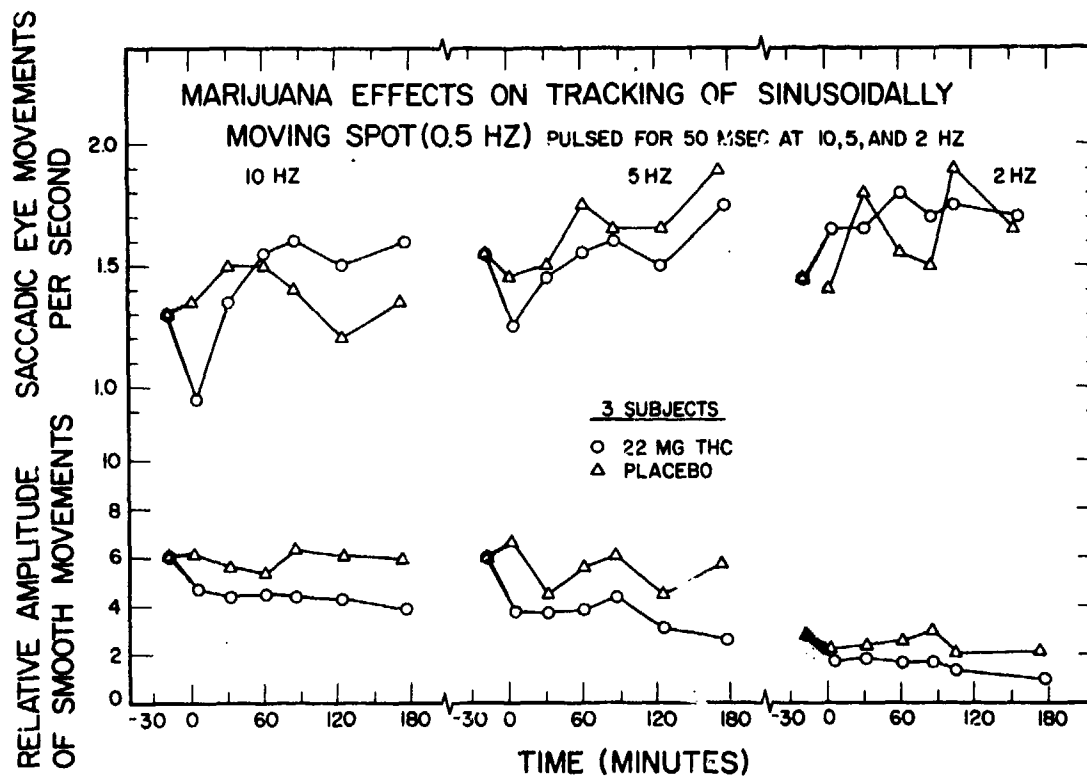


Fig. 9: Time course of marijuana (22 mg THC) and placebo effects on eye tracking of sinusoidally moving spot (0.5 Hz) pulsed for 50 msec at 10, 5, and 2 times/sec for group (3 subjects).

F. Glare Recovery

1. Procedure

Glare recovery is measured as the time required for the eye(s) to recover to a predetermined performance (e.g., seeing moving vertical stripes) after exposure to a bright glaring light.

After adapting to a predetermined luminance level (approximately 1 ft L) in a structureless field, a high intensity uniform light flash (covering about a 100 degree field) was delivered to both eyes. At the same time, the preadapting light was extinguished and a striped grating pattern was presented as moving across the whole field. Immediately after the glare, however, the stripes are not seen by the subject; only after a period of time, designated "glare recovery," was the subject able to see the stripes. At about the time of perception of stripes, an involuntary optokinetic nystagmus (OKN) is elicited. The subjects were required to press a button immediately upon seeing the stripes. The subject's eye movements were detected by sensors attached to the glare unit, and these signals, together with the subject's button press and timing information from the flash units, were recorded on a Beckman polygraph.

In a previous report, (Jampolsky *et al.*, 1973) objective and subjective glare recovery times (GRT) were determined after both marijuana and alcohol treatments. The mean reduction in GRT for 14 subjects after smoking marijuana was very small (0.2 sec) but statistically significant, suggesting a slightly improved ability to recover from a high intensity flash. No clear trend emerged for 3 subjects tested after drinking alcohol. All glare recovery times were measured using high contrast stripes, and consequently the times were quite short (approximately 2 sec).

The present experiments were designed to determine glare recovery times (a) for high and low contrast stripes in a sample of subjects after alcohol ingestion, and (b) for low contrast stripes in a sample of subjects after taking a high dose of marijuana (22 mg THC). Glare recovery measurements for this experiment were determined from subjective responses.

2. Results and Comments

a. Alcohol

Eight subjects were subjected to a high intensity glare flash, and their GRT's for high and low contrast stripes were determined after drinking 1.0 ml/kg of alcohol. For high contrast stripes, there was a slight reduction in GRT for the group following alcohol (Table XV and Fig. 10).

SUBJECT	ALCOHOL 1.0 ml/kg				ALCOHOL PLACEBO				ALCOHOL MINUS PLACEBO			
	Pre 20	Post 60	Post 120	Post 180	Pre 20	Post 60	Post 120	Post 180	Pre 20	Post 60	Post 120	Post 180
127	1.8	1.7	1.4	1.1	1.9	1.8	1.9	1.9	-0.1	-0.1	-0.5	-0.8
128	-	1.3	1.8	1.9	1.3	1.6	1.7	1.2	-	-0.3	0.1	0.7
129	1.5	1.4	1.9	2.7	1.9	2.3	1.9	2.0	-0.4	-0.9	0	0.7
130	2.1	1.9	1.9	1.7	2.2	2.0	1.4	2.1	-0.1	-0.1	0.5	-0.4
131	1.0	1.4	1.2	0.8	2.0	1.3	1.8	1.0	-1.0	0.1	-0.6	-0.2
132	2.2	1.5	2.3	1.8	1.4	1.6	1.8	1.2	0.8	-0.1	0.5	0.6
134	2.9	3.3	3.3	3.8	1.3	2.2	1.8	2.9	1.1	1.1	1.5	0.9
135	2.4	1.0	0.9	0.7	1.1	1.1	1.5	2.2	1.3	-0.1	-0.6	-1.5
Mean	1.99	1.69	1.84	1.81	1.70	1.74	1.73	1.31	0.23	-0.05	0.11	0.00
St. Dev.	0.62	0.70	0.74	1.04	0.39	0.42	0.18	0.64	0.85	0.55	0.72	0.87
Diff. Pre 20	-	-0.30	-0.15	-0.18	-	0.04	0.03	0.11	-	-0.18	-0.12	-0.23
% Diff.	-	-15.00	-7.54	-9.00	-	2.35	1.76	6.50	-	-	-	-

Table XV. Glare Recovery Time (Secs) to High Contrast Stripes: Alcohol (1.0 ml/kg) and Placebo for 8 Subjects. Absolute Times and Times Relative to Placebo Change.

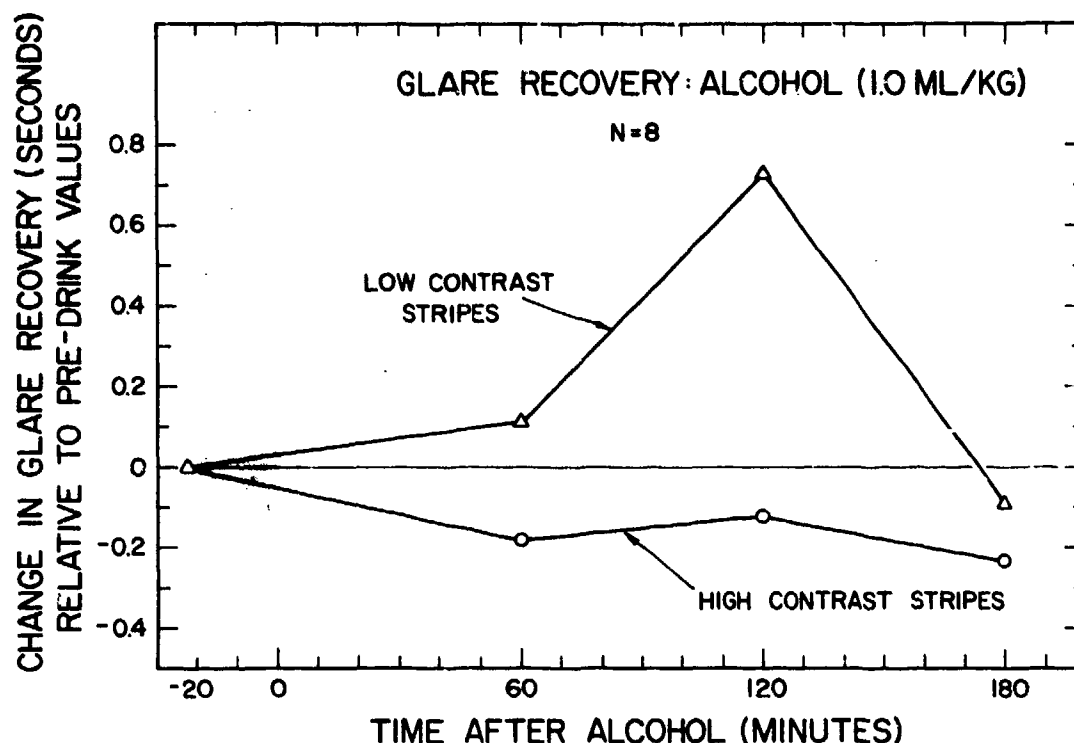


Fig. 10: Time course of change in glare recovery time (secs) to low and high contrast stripes following high intensity brief flash; alcohol (1.0 ml/kg) for 8 subjects. Times relative to placebo change.

For low contrast stripes, on the other hand, there seems to be an *increase* in GRT for the group, reflecting increased times for 4 of the subjects; this is particularly evident at a point two hours after drinking alcohol (Table XVI and Fig. 10). The mean change in GRT relative to pre-drink and placebo values reached a maximum of 0.7 sec 2 hr after drinking. Each individual's change in glare recovery time with alcohol can be compared to his change with the placebo. This comparison is made in Tables XV and XVI.

Since alcohol characteristically increases reaction time, the reduced GRT for high contrast stripes is surely conservative and may be additionally reduced by some 12 to 15 percent (Cavett, 1938). On the other hand, the increased GRT for low contrast stripes at 120 min post-drink presumably includes a component reflecting this change in reaction time. It is not, at present, clear what aspects of alcohol intoxication would produce these results.

SUBJECT	ALCOHOL 1.0 ml/kg				ALCOHOL PLACEBO				ALCOHOL MINUS PLACEBO			
	Pre 20	Post 60	Post 120	Post 180	Pre 20	Post 60	Post 120	Post 180	Pre 20	Post 60	Post 120	Post 180
127	5.0	4.7	6.2	5.3	5.0	4.9	5.2	4.7	0	-0.2	1.0	0.6
128	5.3	6.2	6.8	6.8	5.2	5.3	5.6	5.6	0.1	0.9	1.2	1.2
129	5.6	6.6	7.9	8.3	7.2	7.4	8.0	7.2	-1.6	-0.8	-0.1	1.1
130	8.5	7.6	7.0	7.0	9.4	7.0	7.0	10.2	-0.9	0.6	0	-3.2
131	4.9	3.2	-	4.5	6.4	5.2	5.6	6.4	-1.5	-2.0	-	-1.9
132	7.1	6.0	7.2	7.4	5.2	5.5	6.1	5.3	1.9	0.5	1.1	2.1
134	13.1	13.0	14.0	14.0	13.3	11.5	10.4	13.6	-0.2	1.5	3.6	0.4
135	5.1	4.0	4.1	2.4	2.9	3.6	5.8	4.2	2.2	0.4	-1.7	-1.8
Mean	6.83	6.41	7.60	6.96	6.83	6.30	6.71	7.15	0.00	0.11	0.73	-0.19
St. Dev.	2.83	3.03	3.07	3.41	3.23	2.42	1.74	3.21	1.42	1.10	1.62	1.87
Diff. Pre 20	-	-0.42	0.77	0.13	-	-0.53	-0.12	0.32	-	0.11	0.73	-0.19
% Diff.	-	-6.15	11.30	1.90	-	-7.76	-1.76	4.70	-	-	-	-

Table XVI. Glare Recovery Time (Secs) to Low Contrast Stripes: Alcohol (1.0 ml/kg) and Placebo for 8 Subjects. Absolute Times and Times Relative to Placebo Change.

b. Marijuana

Two subjects were tested with 2 marijuana doses (12 mg THC and 22 mg THC) and marijuana placebo. In each case, GRT was measured for low contrast stripes. Both subjects increased their GRT after smoking the high dose (22 mg THC) of marijuana, although at different times after smoking. The time course of GRT for 2 marijuana doses and the marijuana placebo are illustrated separately for each subject in Figs. 11 and 12, plotted from the data of Table XVII. The change in GRT appears to be dose related, inasmuch as the larger changes occurred for the higher dose of marijuana in both subjects. A larger sample should be studied to confirm the suggested GRT and dose relationship.

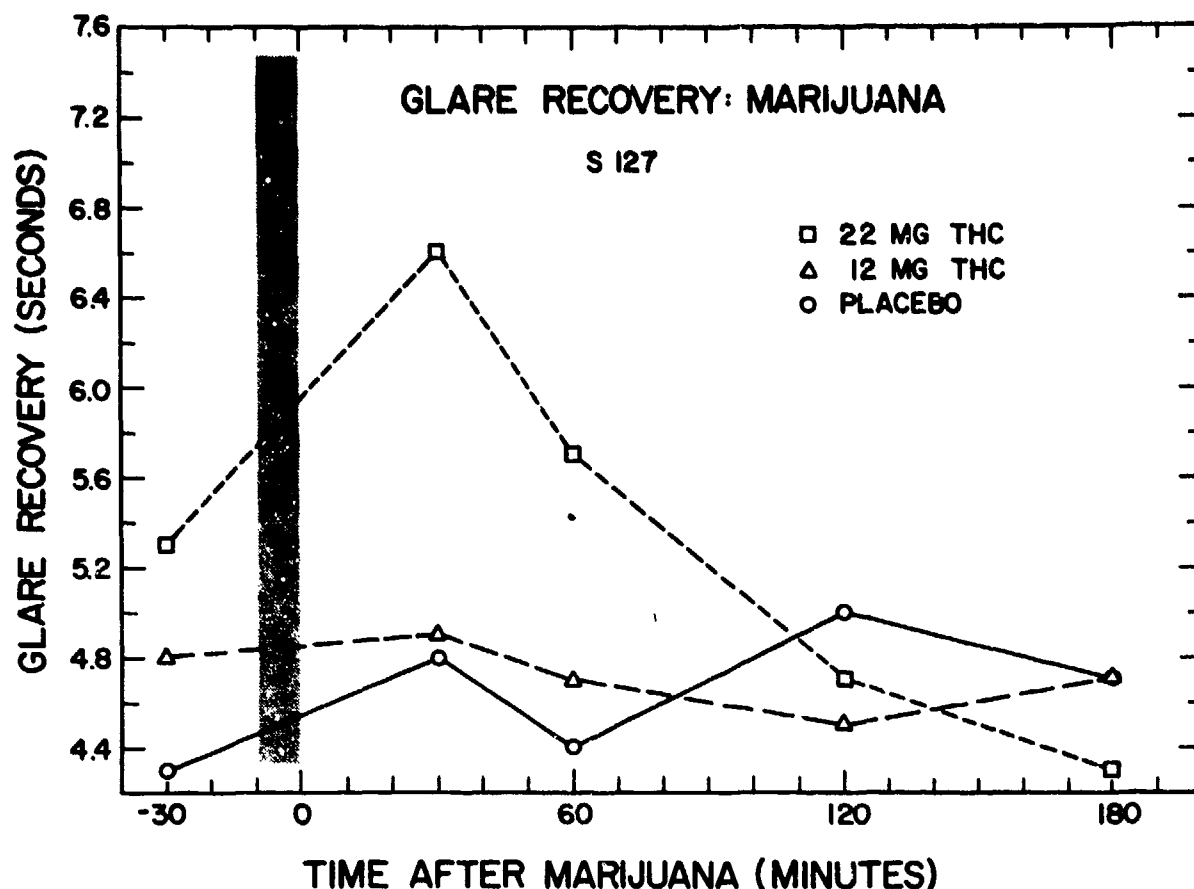


Fig. 11: Time course of glare recovery time (secs) to low contrast stripes following high intensity flash; marijuana (12 and 22 mg THC) and placebo. Subject S127.

SUBJ	MARIJUANA 12 mg THC					MARIJUANA PLACEBO					MARIJUANA MINUS PLACEBO				
	Pre 30	Post 30	Post 60	Post 120	Post 180	Pre 30	Post 30	Post 60	Post 120	Post 180	Pre 30	Post 30	Post 60	Post 120	Post 180
127	4.8	4.9	4.7	4.5	4.7	4.3	4.8	4.4	5.0	4.8	0.5	0.1	0.3	-0.5	-0.1
128	7	5.6	6.1	5.1	5.8	6.0	5.5	5.0	6.3	5.9	-0.3	0.1	1.1	-1.2	-0.1
Mean	5.3	5.3	5.4	4.8	5.2	5.2	5.2	4.7	5.7	5.4	0.1	0.1	0.7	-0.9	-0.1

SUBJECT	MARIJUANA 22 mg THC					MARIJUANA PLACEBO					MARIJUANA MINUS PLACEBO				
	Pre 30	Post 30	Post 60	Post 120	Post 180	Pre 30	Post 30	Post 60	Post 120	Post 180	Pre 30	Post 30	Post 60	Post 120	Post 180
127	5.3	6.6	5.7	4.7	4.3	(SEE ABOVE)					1.0	1.8	1.3	-0.3	-0.5
128	4.7	5.7	6.4	7.8	5.6						-1.3	0.2	1.4	1.5	-0.3
Mean	5.0	6.1	6.0	6.3	4.9						-0.15	1.0	1.35	0.6	-0.4

Table XVII. Glare Recovery Time (Secs) to Low Contrast Stripes: Marijuana (12 and 22 mg THC) and Placebo for 2 Subjects. Absolute Times and Times Relative to Placebo Change.

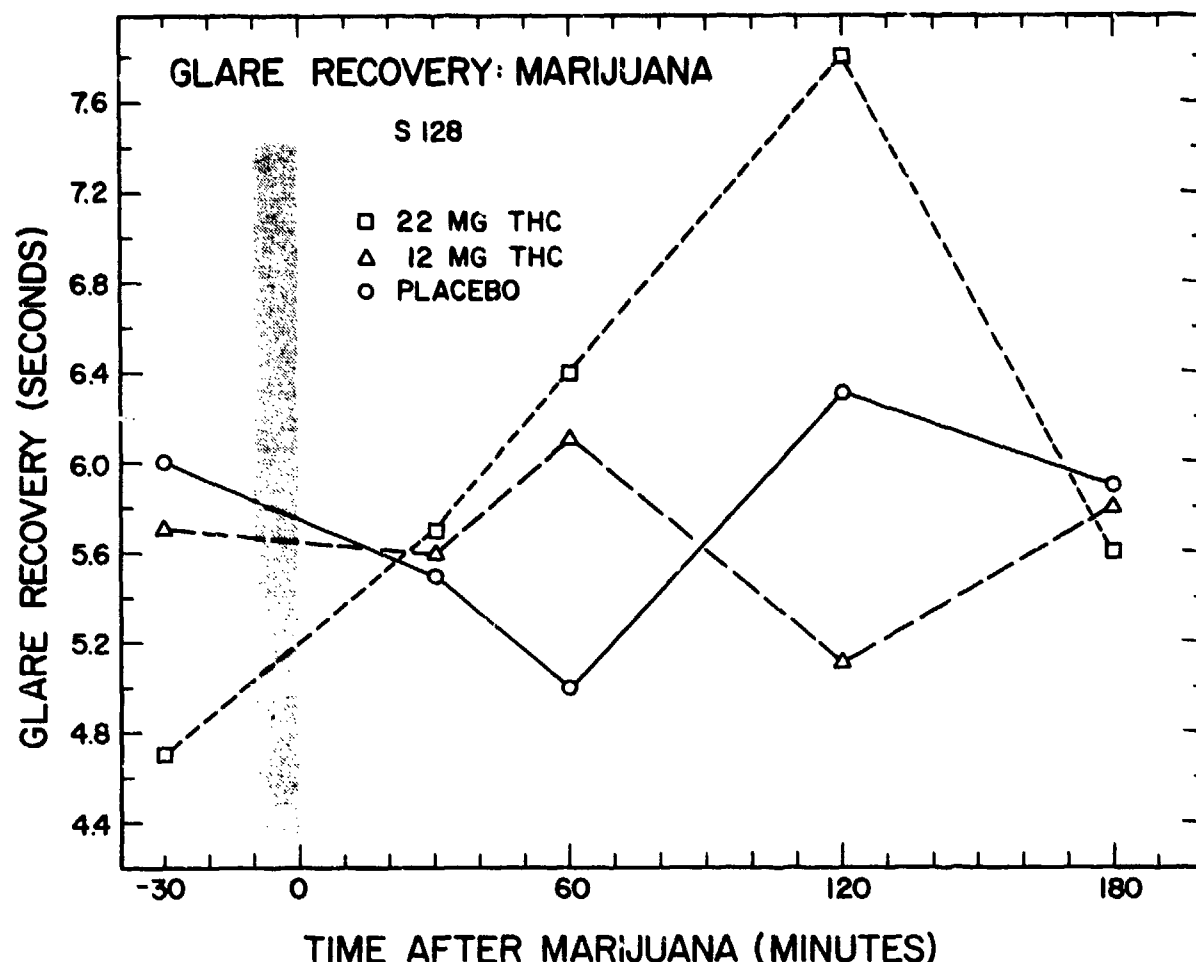


Fig. 12: Time course of glare recovery time (secs) to low contrast stripes following high intensity flash; marijuana (12 and 22 mg THC) and placebo. Subject S128.

G. Visual Acuity

1. Procedure

Distance visual acuity was measured in two different ways: one allowing objective acuity determination and the other using a psychophysical method. Objective endpoints were obtained using changes in eye tracking performance to stimuli of reduced contrast. In the psychophysical procedure (which is a modification of that used by Flom *et al.*, 1963), the subject was required to state the orientation of Landolt rings of different sizes. A plot of percent correct responses as a function of letter size was thus obtained; the data were subjected to probit analysis to determine the 50% acuity threshold and the slope of the psychophysical function at this threshold point.

Two subjects participated in the experiment; they smoked marijuana (12 and 22 mg THC) and a marijuana placebo. Acuity was determined by both methods described above before and at different times after smoking.

2. Results and Comments

Marijuana did not appear to alter the visual acuity of either subject at these dose levels. The individual results and the mean acuities are presented in Table XVIII; the time course of the measurements for the 2 subjects are shown in Fig. 13 and 14. The relative changes in acuity are small for both measures; the objectively determined measures show less variability than the subjective measures. The slopes of the functions relating percent correct responses to letter size are essentially constant across threshold determinations.

The result of the current experiment is consistent with the findings of the LeDain Report (1972). The limited, but carefully obtained, evidence to date indicates that for doses up to 22 mg THC and for subjects with normal acuity, there is little if any systematic change in visual acuity with time after smoking.

SUBJECT		MARIJUANA 22 mg THC					MARIJUANA 12 mg THC					MARIJUANA PLACEBO				
		Pre 30	Post 15	Post 60	Post 115	Post 200	Pre 30	Post 15	Post 60	Post 115	Post 200	Pre 30	Post 15	Post 60	Post 115	Post 200
RINGS	127	107.8	102.4	105.5	104.6	105.5	105.0	108.4	103.9	104.8	105.0	108.4	113.3	114.8	105.5	105.1
		(0.14)	(0.09)	(0.11)	(0.10)	(0.11)	(0.11)	(0.14)	(0.10)	(0.14)	(0.11)	(0.26)	(0.25)	(0.19)	(0.11)	(0.14)
	128	102.4	101.1	108.8	100.7	101.7	102.4	104.3	103.9	102.4	100.8	100.0	101.1	100.7	100.8	100.1
		(0.09)	(0.09)	(0.18)	(0.15)	(0.11)	(0.09)	(0.10)	(0.10)	(0.09)	(0.03)	(0.11)	(0.09)	(0.15)	(0.09)	(0.10)
Mean, %		105.1	101.8	107.2	102.7	103.6	103.7	106.4	103.9	103.6	102.9	104.2	107.2	107.8	103.2	102.6
Mean Slope		(0.12)	(0.09)	(0.15)	(0.13)	(0.11)	(0.10)	(0.12)	(0.10)	(0.12)	(0.10)	(0.19)	(0.16)	(0.17)	(0.10)	(0.12)
Diff. Pre 30, %			-3.3	2.1	-2.4	-1.5		2.7	0.2	-0.1	-0.8		3.0	3.6	-1.0	-1.6
Diff. Pre 30, Slope			-0.03	0.03	0.01	-0.01		0.02	0.0	0.02	0.0		-0.03	-0.02	-0.09	-0.07
SPOT	127	103.5	102.6	104.5	105.6	105.0	105.0	105.5	103.5	104.7	102.5	105.0	105.2	102.5	103.7	104.5
	128	102.7	104.0	105.5	103.0	103.5	104.5	106.0	104.0	105.0	105.0	106.5	105.6	104.0	106.5	104.7
	Mean	103.1	103.3	105.0	104.3	104.3	104.8	105.8	103.8	104.9	103.8	105.8	105.4	103.3	105.1	104.6
Diff. Pre 30, %			0.2	1.9	1.2	1.2		1.0	-1.0	0.1	-1.0		-0.4	-2.5	-0.7	-1.2

Table XVIII: Visual Acuity (Snell-Sterling Percent) for Lando't Rings and Spot Contrast: Marijuana (12 and 22 mg THC) and Placebo for 2 Subjects.

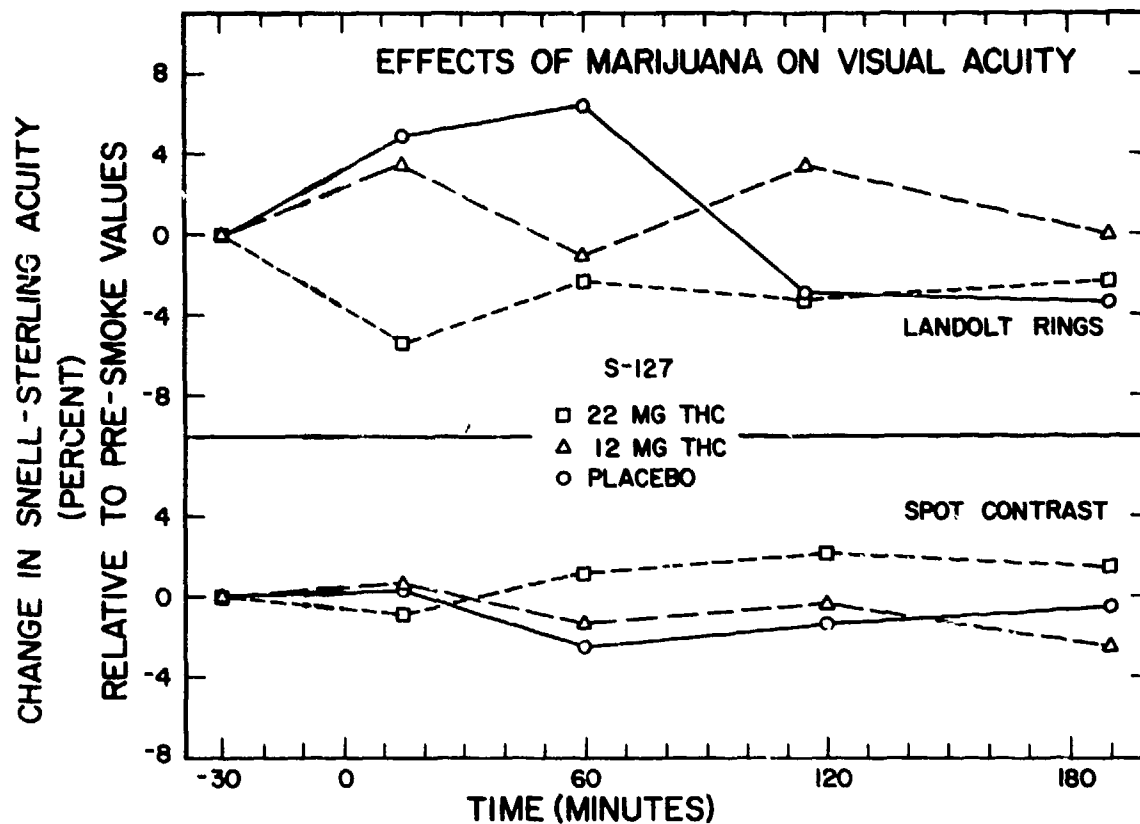


Fig. 13: Effect of marijuana (12 and 22 mg THC) and placebo on visual acuity change (Snell-Sterling percent) for Subject S127. Acuity measured with Landolt rings (above) and threshold spot contrast (below).

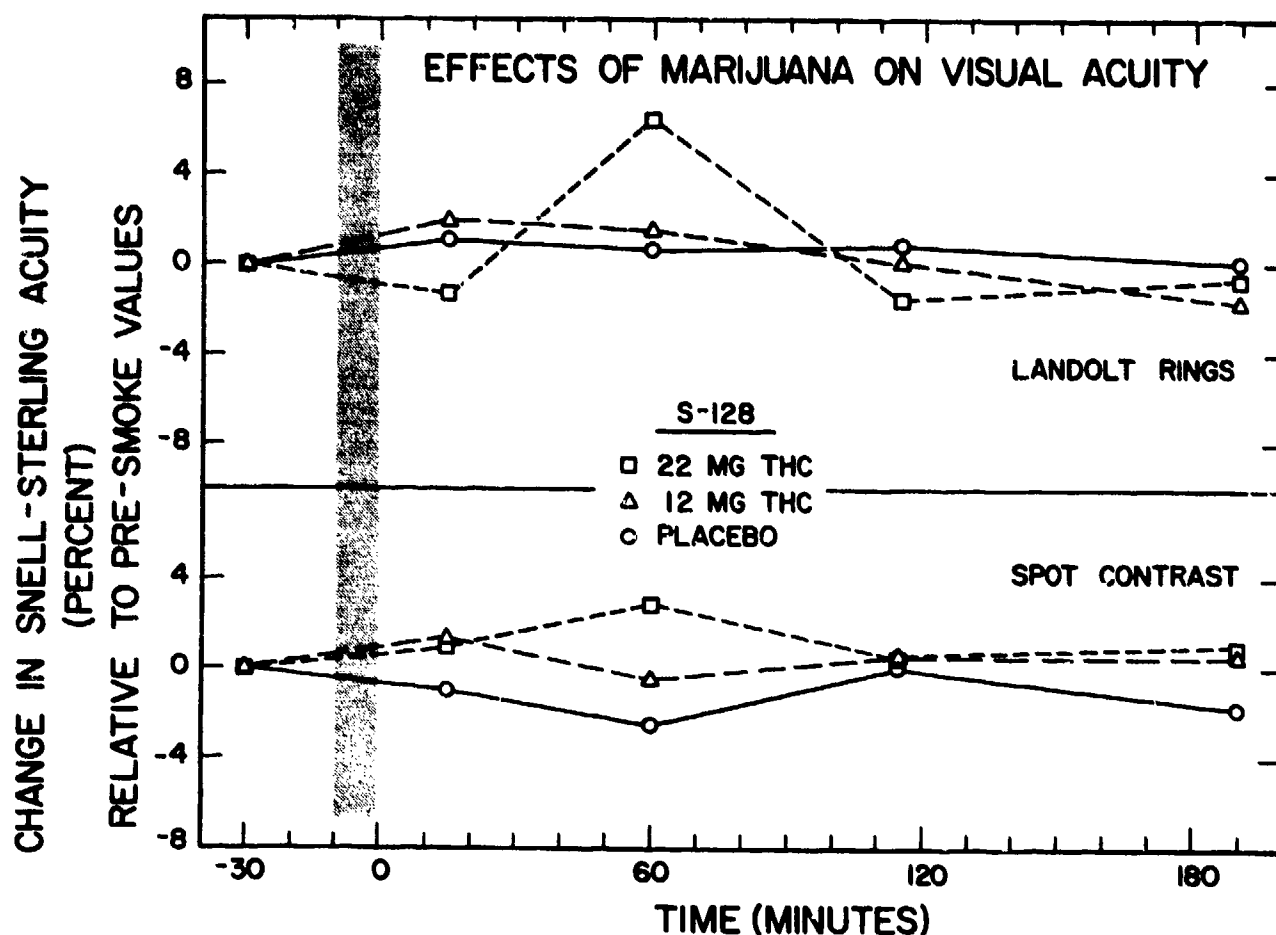


Fig. 14: Effect of marijuana (12 and 22 mg THC) and placebo on visual acuity change (Snell-Sterling percent) for Subject S128. Acuity measured with Landolt rings (above) and threshold spot contrast (below).

H. Spot Luminance Thresholds

Moskowitz *et al.* (1972) have reported that alcohol and marijuana reduced sensitivity to light flashes presented in the retinal periphery. The stimuli were randomly presented within 20 sec time periods (denoted by auditory stimuli); the subject was required to release a switch whenever he saw a peripheral light. Percentage correct responses and reaction times were recorded for stimuli from 18 degrees beyond a previously determined "static peripheral limit" to 48 degrees closer to the fixation point than this limit.

The experiments of Moskowitz *et al.* were conducted under 3 conditions of central processing load. In the first, the subject simply fixated a point of light. In the second and third, the subject had to count the number of randomly presented 100 msec extinctions of the fixation light which occurred at 2 rates in the different phases of the experiment. No account was taken of the time of stimulus presentation during the 20-sec period.

It has been shown (Moskowitz and Burns, 1971) that alcohol slows processing time such that divided attention tasks are performed poorly. However, the generally good performance with alcohol for single tasks (Moskowitz *et al.*, 1972) presumably reflects the relatively unimportant role of processing time for such tasks.

On the other hand, it has been suggested that marijuana affects central processing such that discrete periods of reduced processing ("dropping out") occur (Tinklenberger *et al.*, 1970; Clark *et al.*, 1970). Consequently, performance on both single and divided attention tasks suffer (Moskowitz *et al.*, 1972).

We have hypothesized that after smoking marijuana, a shorter interval between alerting signal and visual stimulus should be associated with a smaller probability that discrete periods of "dropping out" will occur. By contrast, we have hypothesized that task performance after alcohol will be much less dependent on the length of the time window into which a stimulus falls.

1. Procedure

The experiment was carried out in the "White Room." At the subject's first visit for the experiment, his threshold was approximately determined by the method of limits. He was given 3 test sessions to become familiar with the experimental procedure. At each test session the subject was seated 6 ft from the screen and instructed to fixate steadily upon a fixation point directly ahead. After an initial warning tone, there was a delay of 1, 2.5, 5, or 10 sec after which a spot (of 30 min diameter) was presented 25 degrees to the left or right of the fixation points for 200 msec at one of five luminance levels. The visual stimulus was always presented 0.5 sec before a second tone, which was the subject's cue to respond by pressing an appropriate button indicating whether he saw the stimulus to the left or right, or not at all. The procedure was then repeated with a different time period between tones and different spot luminance. The order of the time periods between tones and of the luminance levels was randomly determined. Five responses were made to each luminance level presented within each time period, so that a total of 100 responses were made in an experimental session. The stimulus presentation for the experiment was controlled by a Hewlett-Packard 9830A Calculator. At the end of the experiment, which required about 25 min, the calculator performed probit analysis on each set of data and printed the 50 percent luminance threshold for each time period.

Ten subjects were used in a double-blind, balanced Latin square design using 2 doses of alcohol (0.5 and 1.0 ml/kg), two doses of marijuana (8 and 1 mg THC), and a double placebo. Subjects were pretested and then required to drink and smoke. They were retested 20 min and 150 min after the end of the smoke/drink period.

2. Results and Comments

a. Alcohol

Table XIX and Fig. 15 show that for the alcohol treatment there are no consistent trends in the data either as a function of dose level or as a function of the time period in which the stimulus was presented. These results are in accord with those of Moskowitz *et al.* (1972).

		THRESHOLD LUMINANCE				CHANGE IN THRESHOLD LUMINANCE							
		30 Min Pre-Treatment				20 Min Post-Treatment				135 Min Post-Treatment			
		sec	sec	sec	sec	sec	sec	sec	sec	sec	sec	sec	sec
		1	2.5	5	10	1	2.5	5	10	1	2.5	5	10
PLACEBO	Mean	0.68	0.69	0.68	0.73	-0.02	-0.03	0.03	-0.03	-0.03	-0.01	0.04	-0.04
	St. Dev.	0.27	0.32	0.22	0.29	0.08	0.11	0.10	0.16	0.07	0.12	0.18	0.15
ALCOHOL 0.5 ml/kg	Mean	0.61	0.63	0.67	0.63	0.06	0.04	-0.01	0.08	-0.00	0.03	-0.03	0.07
	St. Dev.	0.24	0.26	0.22	0.25	0.11	0.17	0.17	0.09	0.11	0.14	0.11	0.13
ALCOHOL 1.0 ml/kg	Mean	0.70	0.77	0.79	0.73	0.02	-0.04	-0.02	0.01	0.11	0.04	-0.11	0.08
	St. Dev.	0.15	0.24	0.19	0.18	0.11	0.16	0.11	0.09	0.18	0.21	0.13	0.15
MARIJUANA 8 mg THC	Mean	0.70	0.75	0.73	0.76	0.06	-0.07	0.04	0.01	-0.00	0.01	-0.05	0.01
	St. Dev.	0.13	0.14	0.13	0.16	0.10	0.10	0.14	0.19	0.17	0.15	0.13	0.22
MARIJUANA 15 mg THC	Mean	0.64	0.67	0.67	0.71	0.01	0.04	0.07	0.14	0.16	0.05	0.11	-0.04
	St. Dev.	0.16	0.18	0.19	0.26	0.16	0.21	0.10	0.20	0.15	0.09	0.09	0.19

Table XIX. Peripheral (25 Degrees Eccentric to Fovea) Luminance Increment Threshold (Log cd/m²): Marijuana (8 and 15 mg THC), Alcohol (0.5 and 1.0 ml/kg) and Placebo Group Means (8 Subjects) for 200 msec Spot Presentation in 1, 2.5, 5, or 10 Sec Interval.

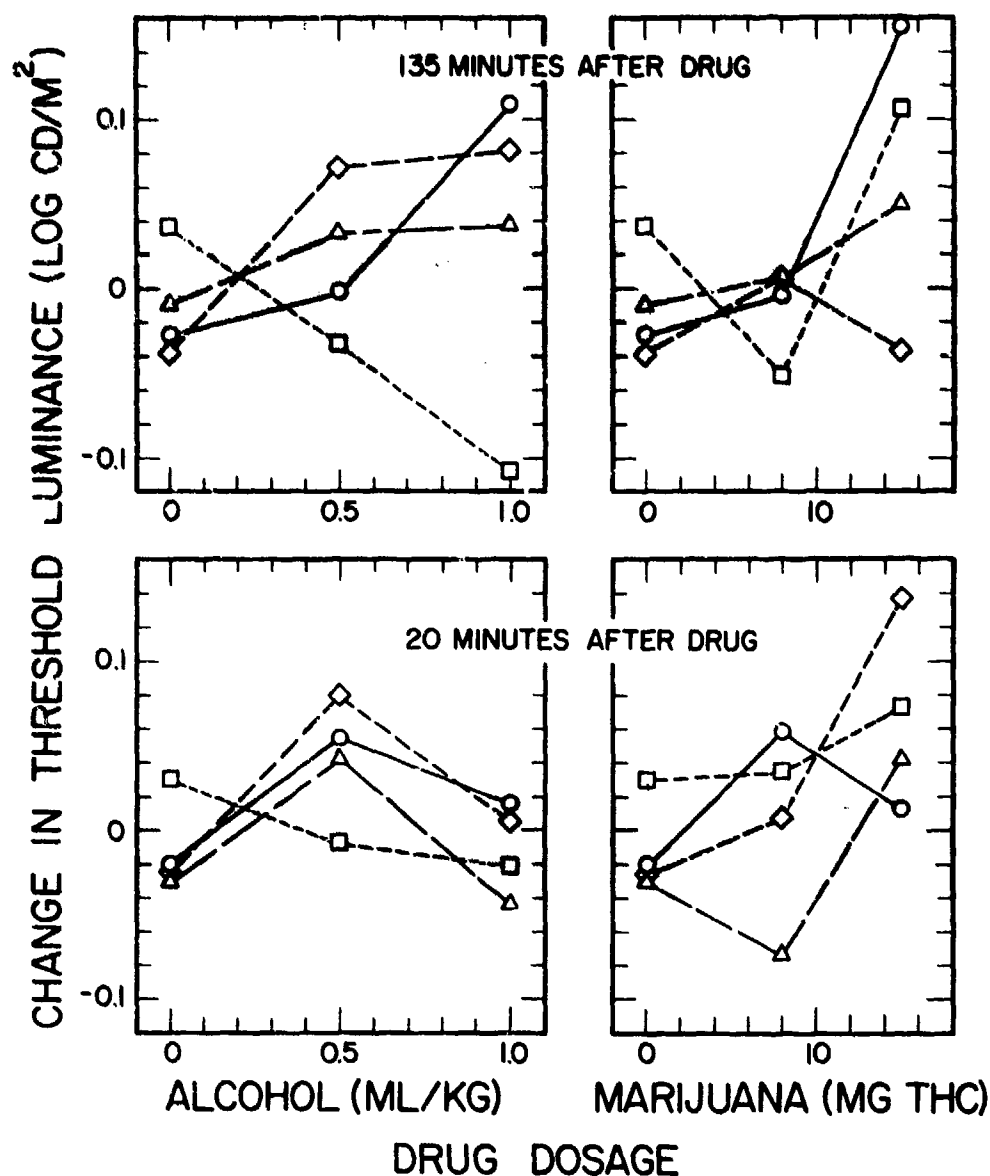


Fig. 15: Change in threshold luminance for 0.5 degree spot 25 degrees in retinal periphery for 1 (o), 2.5 (Δ), 5 (■), and 10 (●) sec time windows (see text).

b. Marijuana

The data for the marijuana treatments (Table XIX and Fig. 15) seem to indicate small increases in threshold with 15 mg THC, although 8 mg THC seemed ineffective compared with the placebo treatment. Moskowitz *et al.* (1972) showed increased peripheral thresholds with marijuana for both single and divided attention tasks. The original hypothesis of "dropping out" by marijuana subjects during the variable time interval before the stimulus is not conclusively supported by the present results.

V. SUMMARY AND CONCLUSIONS

This study was directed toward elucidating vision changes after administering alcohol or marijuana. In order to assess changes in vision functions independently of changes in the subjective response functioning of subjects, we have stressed, where possible, automatic devices and systems which rely on objective or reflex functioning to determine test endpoints.

In the past year we have measured 7 vision functions. We have established a close relation between drop in intraocular pressure and marijuana for marijuana doses from 0 to 22 mg THC. This result firmly established the conclusion that marijuana smoking induces a fall in IOP, but we find such a relation only in subjects who experience a sense of peaceful relaxation under drug influence. These subjects tend to be light to moderate users of marijuana (less than 4 or 5 joints per week); we would like to confirm and extend these findings by inducing a tolerance to marijuana in a group of subjects and measuring IOP drop over the 3 to 4 days in which tolerance is established. We expect that the drop of IOP would be markedly and progressively reduced in such a group during this period.

We have demonstrated a drug-induced alteration in proximal vergence (that component of convergence which is induced by target proximity in vision testing instruments). This result has important implications for subjective and objective test devices in which targets are optically placed at infinity. Many such devices are used as vision screeners in transportation and in the military. It is important in assessing the results of such tests to know how subjects' responses may be altered under the influence of drugs.

Our results on sinusoidal pursuit eye tracking have confirmed and extended those which we reported last year (Jampolsky *et al.*, 1973). High frequency cutoff after alcohol was reduced substantially; after marijuana it was unchanged. We have included in our test battery a test of sinusoidal pursuit eye movements in which information concerning target motion is reduced by intermittently removing the target from the view of the subject. The subject is forced to make predictions of future target position if he is to continue to track accurately. In this situation, which may have important implications for real world tracking performance (moving targets disappear behind trees, buildings, etc., or are only illuminated intermittently), subjects affected by alcohol or, to a lesser extent, marijuana show markedly decreased ability to track. These experiments are currently being extended with development of more sophisticated analysis techniques.

The preliminary assessment we have made of optokinetic nystagmus (OKN) for subjects under alcohol has led us to question its usefulness as an objective test endpoint for glare recovery time for these subjects. Any reduction of regularity or amplitude of OKN under alcohol could contaminate our test results on glare recovery.

Glare recovery time is a potentially important factor in military situations and in transportation. Our preliminary results for high contrast objects provide reassurance that in our sample of young subjects drug induced changes are unlikely to prove hazardous. For low contrast objects, our results indicate increased glare recovery times under both alcohol and marijuana. Furthermore, we have dealt only with young subjects; whether older subjects would react in the same way under alcohol or marijuana intoxication is worthy of investigation.

Our results on visual acuity show no changes in acuity after marijuana intoxication. There are, to our knowledge, no reports of such changes in the literature. There was less variation in the contrast measure of acuity than in the Landolt C measure which we used.

The results of our peripheral luminance discrimination experiments indicate a slightly increased threshold with marijuana but no effect of alcohol, tending to support the findings of others (e.g., Moskowitz *et al.*, 1972). We regard these results as a necessary preliminary to establishing levels of visual performance under conditions more related to real-world tasks. Our Special Vision Testing Facility can be readily adapted to perform this phase of the experiment, in which subjects will be required to perform a quantifiable central task while responding to peripherally presented targets.

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